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Murad Alam

PROCEDURES IN COSMETIC DERMATOLOGY

FOURTH EDITION

Lasers and Lights

Edited by
George J. Hruza
Elizabeth L. Tanzi

ELSEVIER

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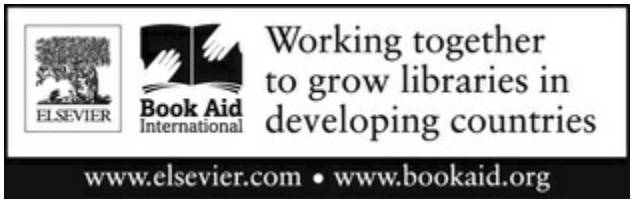
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Series preface

Much has changed since the first edition of this series. Non-invasive and minimally invasive cosmetic procedures, as pioneered by dermatologists, have become increasingly adopted by physicians and well-accepted by patients. Cosmetic dermatologic surgery procedures have been refined and improved. Interventions have become more effective, and also safer and more tolerable with increasing benefit: risk ratios. Combination cosmetic regimens that include multiple procedure types have been shown to achieve results comparable to those with more invasive procedures. And new devices and technologies continue to be introduced.

And how best to keep up with these advances and to ensure your offerings are state of the art and at the cutting edge? The newest edition of the Procedures in Cosmetic Dermatology series keeps you there, and for those starting out in the field these texts quickly introduce you and bring you to the state of the art. Each book in this series is designed to quickly impart basic skills as well as advanced concepts in an easy-to-understand manner. We focus not on theory but on how-to. Our expert book editors and chapter authors will guide you through the learning process efficiently, so you can soon get back to treating patients.

The authors are leading dermatologists in the field. Dermatologists' role in cosmetic medicine has continued to expand. Research has revealed that primary care physicians and the general public view dermatologists as the experts in less invasive cosmetic procedures. A nationwide advanced fellowship program in cosmetic dermatologic surgery has been initiated to train the next generation of dermatologists to the highest standards.

What has not changed is physicians' need for clear, concise, and current direction on procedure techniques. Physicians need to be proficient in the latest methods for enhancing appearance and concealing the visible signs of aging.

To that end, we hope that you, our reader, find the books enjoyable and educational.

We thank our many contributors and wish you well on your journey of discovery.

Jeffrey S. Dover MD, FRCPC, FRCP, Murad Alam MD, MSCI

Series preface first edition

Although dermatologists have been procedurally inclined since the beginning of the specialty, particularly rapid change has occurred in the past quarter century. The advent of frozen section technique and the golden age of Mohs skin cancer surgery has led to the formal incorporation of surgery within the dermatology curriculum. More recently technological breakthroughs in minimally invasive procedural dermatology have offered an aging population new options for improving the appearance of damaged skin.

Procedures for rejuvenating the skin and adjacent regions are actively sought by our patients. Significantly, dermatologists have pioneered devices, technologies, and medications, which have continued to evolve at a startling pace. Numerous major advances, including virtually all cutaneous lasers and light-source-based procedures, botulinum exotoxin, soft tissue augmentation, dilute anesthesia liposuction, leg vein treatments, chemical peels, and hair transplants have been invented or developed and enhanced by dermatologists. Dermatologists understand procedures, and we have special insight into the structure, function, and working of skin. Cosmetic dermatologists have made rejuvenation accessible to risk-averse patients by emphasizing safety and reducing operative trauma. No specialty is better positioned than dermatology to lead the field of cutaneous surgery while meeting patient needs.

As dermatology grows as a specialty, an ever-increasing proportion of dermatologists will become proficient in the delivery of different procedures. Not all dermatologists will perform all procedures, and some will perform very few, but even the less procedurally directed among us must be well versed in the details to be able to guide and educate our patients. Whether you are a skilled dermatologic surgeon interested in further expanding your surgical repertoire, a complete surgical novice wishing to learn a few simple procedures, or somewhere in between, this book and this series are for you.

The volume you are holding is one of a series entitled *Procedures in Cosmetic Dermatology*. The purpose of each book is to serve as a practical primer on a major topic area in procedural dermatology.

If you want to make sure you find the right book for your needs, you may wish to know what this book is and what it is not. It is not a comprehensive text grounded in theoretical underpinnings. It is not exhaustively referenced. It is not designed to be a completely unbiased review of the world's literature on the subject. At the same time, it is not an overview of cosmetic procedures that describes these in generalities without providing enough specific information to actually permit someone to perform the procedures. Importantly, it is not so heavy that it can serve as a doorstop or a shelf filler. What this book and this series offer is a step-by-step, practical guide to performing cutaneous surgical procedures. Each volume in the series has been edited by a known authority in that subfield. Each editor has recruited other equally practical-minded, technically skilled, hands-on clinicians to write the constituent chapters. Most chapters have two authors to ensure that different approaches and a broad range of opinions are incorporated. On the other hand, the two authors and the editors also collectively provide a consistency of tone. A uniform template has been used within each chapter so that the reader will be easily able to navigate all the books in the series. Within every chapter, the authors succinctly tell it like they do it. The emphasis is on therapeutic technique; treatment methods are discussed with an eye to appropriate indications, adverse events, and unusual cases. Finally, this book is short and can be read in its entirety on a long plane ride. We believe that brevity paradoxically results in greater information transfer because cover-to-cover mastery is practicable.

We hope you enjoy this book and the rest of the books in the series and that you benefit from the many hours of clinical wisdom that have been distilled to produce it. Please keep it nearby, where you can reach for it when you need it.

Jeffrey S. Dover MD, FRCPC, FRCP, Murad Alam MD, MSCI

Preface

The tremendous advances to the field of laser, light, and device-based dermatologic treatments continue at a speed that can make it difficult for even the most diligent practitioner to stay abreast of the most important developments. Out of a need for the most up-to-date information, the *Lasers and Lights* series was created. This fourth edition of *Lasers and Lights* captures the numerous developments in our field since the last edition. Written by key opinion leaders in the field of cutaneous laser surgery, chapters have been revised to include the latest breakthroughs in both technology and technique for each topic.

Several chapters have been expanded to capture new treatments that were not available during the writing of the last edition. There is expanded coverage of high-intensity ultrasound, cryolipolysis, and radiofrequency energy sources. However, in keeping with previous editions, the book begins with an excellent overview of the fundamentals and basic science of cutaneous laser, light, and device-based surgery. Subsequent chapters include: vascular-specific lasers, laser hair removal, nonablative laser and light skin rejuvenation, nonablative fractional resurfacing, ablative fractional resurfacing, fully ablative laser skin resurfacing, nonsurgical body contouring, and nonsurgical skin tightening. The chapters devoted to the treatment of pigmented lesions and tattoos and the laser treatment of ethnic skin have been updated with the most current information on the exciting development of picosecond lasers. A review of complications and legal considerations of cutaneous laser and device-based treatments concludes the book.

In keeping with the goal of the entire series, the book is written to provide comprehensive, yet practical information on a variety of topics. Chapters highlight proper patient selection, treatment considerations, practical pearls, and potential side effects and complications. Written for the benefit of the novice and experienced cutaneous laser surgeon alike, authors include basic and advanced techniques discussed in a concise, straightforward manner. With the addition of clinical photographs, graphic illustrations, practice pearls, tables, clinical cases, key points, videos and charts, the reader will gain valuable insight beyond the written text. We are confident that *Lasers and Lights*, fourth edition will provide the reader with an outstanding and timely overview of the use of lasers, light sources and other energy-based devices within the rapidly

changing field of cosmetic dermatology.

George J. Hruza MD, MBA, Elizabeth L. Tanzi MD, FAAD

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Dedication

To my "Hrilliams" family: my wife Carrie Hruza, OD and our children, Stephanie and Paul Hruza and Hope and Rose Williams for giving my life joy and fulfillment.

To my parents: Drs. Judita and Zdenek Hruza for their support and encouragement in pursuing my medical career and their unwavering love.

In memory of my mother, Judita Hruza, MD, with her Holocaust experiences of inhumanity and survival and her incredible zest for life, forgiveness, and sacrifice, she inspired many and will always be an inspiration to me to live life to the fullest with charity and grace.

George J. Hruza MD, MBA

To my parents, Joe and Lyn, who taught me through example the power of an unpretentious yet unwavering work ethic.

To my wonderful husband, Big Pete, whose love, support and attitude inspire me to always take on the next challenge.

To my children, Peter and Katie, who remind me every day what is truly important in life. Oh, how I love those smiles!

Elizabeth L. Tanzi MD, FAAD

To the women in my life: my grandmothers, Bertha and Lillian, my mother, Nina, my daughters, Sophie and Isabel, and especially to my

wife, Tania. For their never-ending encouragement, patience, support, love, and friendship.

To my father, Mark – a great teacher and role model; to my mentor, Kenneth A. Arndt for his generosity, kindness, sense of humor, joie de vivre, and above all else curiosity and enthusiasm.

Jeffrey S. Dover MD, FRCPC, FRCP

Elsevier's dedicated editorial staff has made possible the continuing success of this ambitious project. The team led by Belinda Kuhn, Humayra Khan and the production staff have refined the concept for this new edition while maintaining the series' reputation for quality and cuttingedge relevance. In this, they have been ably supported by the graphics shop, which has created the signature high-quality illustrations and layouts that are the backbone of each book. We are also deeply grateful to the volume editors, who have generously found time in their schedules, cheerfully accepted our guidelines, and recruited the most knowledgeable chapter authors. And we especially thank the chapter contributors, without whose work there would be no books at all. Finally, I would also like to convey my debt to my teachers, Kenneth Arndt, Jeffrey Dover, Michael Kaminer, Leonard Goldberg, and David Bickers, and my parents, Rahat and Rehana Alam.

Murad Alam MD, MSCI

1

Understanding lasers, light sources, other energy-based technology

Catherine M. DiGiorgio, R. Rox Anderson, Fernanda H. Sakamoto

Summary and Key Features

- Lasers and flashlamps can destroy histologic targets using the concept of selective photothermolysis (SP).
- Ablative lasers vaporize tissue; nonablative lasers heat tissue without vaporization.
- Selective histologic damage requires heat confinement to desirable target structures. SP combines appropriate wavelength ("color" of light), fluence ("dose" of light), pulse duration, and protective skin cooling for the treatment of a variety of diseases.
- Understanding the optical and thermal properties of skin and its histologic targets allows safe and optimal treatments using light sources.
- Other energy-based technologies can be used to treat specific skin targets by either heating (radiofrequency, ultrasound), mechanical injury (ultrasound, stress waves), cooling (cryolipolysis), or stimulating mitochondrial function (photobiostimulation).

Light

Light is a fundamental form of energy with numerous medical applications. At the quantum level, light is composed of packets of energy known as photons. Each photon carries a discrete amount of energy. Light is also an

electromagnetic wave. The electromagnetic spectrum extends from low-frequency radio waves to ultra-high-energy gamma rays. The energy carried by each photon is determined by its wavelength, which for visible light (400 to 700 nm) corresponds to its color. Laser is an acronym for *light amplification by the stimulated emission of radiation*. Stimulated emission is a quantum process by which one photon can stimulate the creation of another photon by interacting with an excited atom or molecule. Lasers work by pumping many atoms into the excited state from which a very large amount of stimulated emission can occur. Laser light is typically monochromatic, meaning that the output is composed of a single wavelength of light. A second characteristic of lasers is coherence, meaning that all waves of light travel in phase spatially and temporally. Laser light is also highly collimated, which allows the laser beam to travel long distances without divergence and to be focused to a spot about equal to its own wavelength. These properties of lasers allow for unique forms of in vivo imaging, such as confocal microscopy and optical coherence tomography.

Lasers are also capable of producing extremely intense, short pulses of light. In dermatology and ophthalmology, pulsed lasers have become mainstream tools for precise surgery and target-selective treatments. Prior to 1983 lasers in dermatology were used primarily for nonspecific tissue destruction. With the description of the theory of selective photothermolysis (SP) by Anderson and Parrish,[1] applications of lasers in dermatology have evolved to a host of devices for more precise, targeted thermal damage, while minimizing nonspecific tissue destruction. Nonlaser flashlamp sources called intense pulsed light (IPL) have also been developed for some of the applications of SP that use millisecond pulses of light. Understanding the theory of SP is vital for making sense of the large number of laser and IPL devices and applications. An understanding of the optical properties of skin is also needed because the whole endeavor of laser treatment starts with the absorption of light energy, inside the skin.

Lasers that vaporize a thin layer or column of tissue have also been developed. The concept of fractional photothermolysis (FP), reported by Manstein et al.,[2] launched another era of lasers in dermatology, in which patterns of very small nonselective thermal damage zones are used to stimulate skin remodeling without scarring. Laser-stimulated remodeling is a complex process that mimics large wound healing in some aspects, with epidermal regeneration, induction of metalloproteinases, and formation of new dermal matrix including elastin fibrils and collagen types I and III. Compared with gross wound healing, there is minimal inflammation and no scarring. A "cookbook" approach should be avoided when choosing among these devices for various applications.

When treating a particular patient with a particular device, a combination of fundamental understanding, careful observation of the appropriate clinical end points, dexterity, and clinical experience is far better than a set of instructions (Box 1.1).

Box 1.1

How to choose a light source?

1. Define clinical indication.

2. Choose correct light wavelength (nm) based on histologic target chromophore.

3. Observe whether continuous wave (CW) or pulsed source is required.

4. Choose right pulse width if necessary (s).

5. Choose pulse frequency (Hz), if necessary.

6. Set skin cooling parameters.

7. Choose appropriate light dose.

8. Test laser to check whether it is working properly.

9. Trigger single pulse on target skin and observe clinical end point.

. Adjust dosimetry if necessary.

. If no unwanted sign is observed, continue with treatment.
Always:

a. Anesthetize area if necessary (e.g., tattoos, ablative lasers).

b. Wear appropriate personal protection (e.g., wavelength-specific eye goggles/glasses, fume-resistant mask, gloves).

c. Turn smoke evacuator on if performing ablative procedures or laser hair removal, and keep within 1–2 cm of target.

d. Dress the area with petrolatum ointment, and protect from sun exposure until healed.

Light interactions with skin

Photons can be absorbed (giving up their energy to matter) or scattered (changing their direction of travel). Light that is scattered back from skin is called reflectance. For a given skin layer, light that passes through it is called

transmittance. Scattering is inversely wavelength-dependent, such that shorter wavelengths are scattered more and longer wavelengths (such as infrared) are scattered less. Similarly, light is both absorbed and scattered within the skin. Thus skin layers are cloudy and colored depending on the mix of scattering and absorption. Penetration of light into (and beyond) skin is limited by both absorption and scattering. All effects of light on the skin begin with photon absorption, and the molecules that absorb light are called chromophores. Ablative lasers are those that vaporize tissue by rapidly boiling water inside the tissue. Therefore it should come as no surprise that the lasers intended for skin ablation are at wavelengths strongly absorbed by water. Nonablative lasers do not vaporize tissue. There are many nonablative lasers in dermatology, some of which are at wavelengths absorbed by water and some of which are absorbed by other chromophores, such as melanin, hemoglobins, tattoo inks, lipids, or pigments.

Pearl 1

Ablative light sources vaporize the skin, whereas nonablative and selective laser treatments can be performed through selective photothermolysis.

Laser dosimetry is extremely important for safe and effective results. To remove tissue, ablative lasers must raise local tissue temperature beyond the boiling point of 100°C, plus the large amount of energy needed for changing water into steam. The fundamental unit of energy is a joule (J). It takes 4.2 J to heat 1 cm^3 of water by 1°C. To vaporize the same 1 cm^3 of water, more than 2000 J are required. An ablative laser must deliver approximately 2500 J of energy per cm^3 of vaporized tissue. Not only is a lot of energy required to ablate skin tissue—the energy must be delivered quickly to remove the hot tissue before heat is conducted deeply into the skin, causing a burn. The standard ablative lasers in dermatology are Er:YAG (2940 nm) and CO_2 (10,600 nm). The desired interaction of these ablative lasers is to precisely remove a thin layer for resurfacing or narrow column for fractional treatment of skin, leaving behind minimal residual thermal damage. A thin residual thermal damage layer, typically approximately 0.1 mm, is useful in practice for hemostasis. Minimum residual thermal injury is achieved with ablative lasers by a combination of wavelength, pulse duration, and power density (W/cm^2) at the skin surface. A common mistake made by beginning laser users is to "turn down" the power of a surgical CO_2 laser in a misguided attempt to exercise caution. Unfortunately, turning down the power can cause burns because the process turns from rapid, precise vaporization with minimal thermal damage to bulk heating of the skin from unwanted residual heat. Fortunately, many of the ablative lasers made specifically for dermatology are designed to stay within a range of dosimetry for rapid tissue ablation, making this scenario less likely. The safest Er:YAG and CO_2 lasers are those emitting high power, high energy, and short (less than a few milliseconds) pulses, designed specifically for dermatologic use with minimal residual thermal damage. Despite whatever safeguards an ablative

laser may offer, the most reliable safeguard is an ability to recognize the desired and undesired immediate response end points.[3,4] For example, immediate contraction of the skin is always a sign that substantial thermal injury of the dermis has occurred (Fig. 1.1).

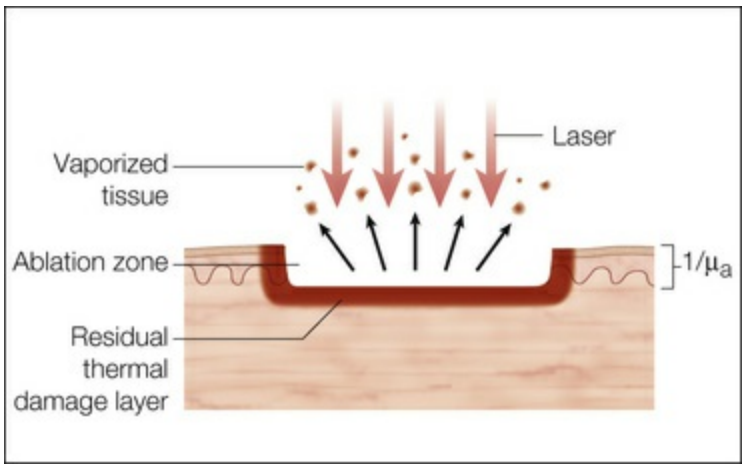


FIGURE 1.1 Scheme of ablative laser vaporizing skin, leaving a residual thermal damage layer.

Fluence is defined as the energy delivered per unit area of skin, and its units are typically expressed in J/cm^2. One can think of fluence as the local "dose" of laser energy applied to skin. Pulse duration (also called pulsewidth or exposure duration) is simply the time for which laser energy is delivered, expressed in seconds. Power is defined as the rate of energy delivery. Power is measured in watts (W), a familiar unit because of common devices such as light bulbs. One watt is defined by 1 W = 1 J/s. A common incandescent light bulb consumes 100 W of electric power but emits less than 10 W of light. In contrast, common lasers in dermatology produce 10 to 1,000,000,000 (a billion) W of light power. The Q-switched lasers, which we commonly use to remove tattoos and pigmented lesions, produce more power than a typical nuclear power plant! However, these lasers emit that impressive power for only 10 to 100 nanoseconds (ns, billionths of a second). Thus the fluence for treatment of a child with a nevus of Ota using a 10 ns Q-switched laser, and of a child with port-wine stain using a 1 millisecond (ms) pulsed dye laser, can be similar—approximately 5 to 10 J/cm^2—but the pulsed dye laser has 100,000 times less power than the Q-switched laser.

Skin optics

In skin the most important chromophores are hemoglobin, melanin, exogenous pigments (e.g., tattoo ink, some drugs), water, and lipids. The intended target chromophore, depth of the target structures, and absorption of light by adjacent tissue influence the appropriate wavelength selection. Absorption spectra of various chromophores across the electromagnetic spectrum are summarized in

Fig. 1.2.

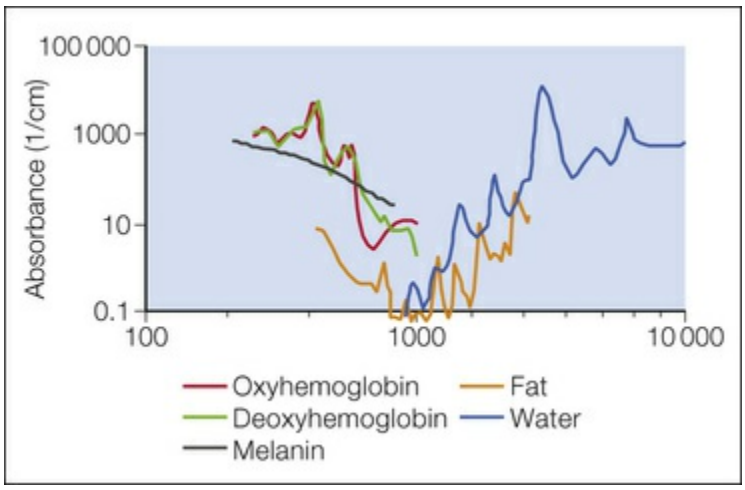


FIGURE 1.2 Absorption spectra of chromophores commonly used for selective photothermolysis laser surgery. This figure was modified from Sakamoto FH, Wall T, Avram MM, et al. Lasers and flashlamps in dermatology. In: Wolff K, Goldsmith LA, Katzet SI, et al. eds. *Fitzpatrick's Dermatology in General Medicine Vol II*. Columbus, OH: The McGraw-Hill Companies, Inc.; 2007:2263–2279.

Selective photothermolysis

SP relies on fundamental choices being made correctly—wavelength, pulse duration, fluence, exposure spot size, and use of skin cooling. First, a wavelength (or, with IPLs, a range of wavelengths) must be used that is preferentially absorbed by the intended "target" structures such as hair follicles, microvessels, tattoo inks, or melanocytes. Thus far all lasers using SP operate in the visible and near-infrared (NIR) spectrum. In the visible light spectrum, a target chromophore is generally treated using wavelengths of light of a complementary color. For example, red tattoo ink absorbs green light and can be effectively treated with a frequency-doubled Q-switched Nd:YAG laser operating at the green wavelength of 532 nm. Similarly, green tattoo ink is best removed with a red Q-switched laser, such as the ruby laser at 694 nm. Preferential absorption implies the avoidance of competing chromophores, not simply strong absorption in the intended target. For example, when treating such dermal targets as blood vessels, it is important to minimize unwanted damage to the epidermis. Because every photon that reaches a blood vessel must first travel through the overlying epidermis, the best wavelengths for port-wine stain treatment are not simply those with strong absorption by blood. The proper wavelength(s) must also penetrate deeply enough to reach the intended targets. Across the visible and NIR spectrum from 400 to 1200 nm, longer wavelengths penetrate deeper into tissue. These reasons account for the use of yellow light pulsed dye lasers rather than the very strongly absorbed blue wavelengths for treating superficial vascular lesions. Long-pulsed dye

lasers are the first example of a laser designed specifically for a medical application: treatment of port-wine stains in children (see Case Study 2). On the microscopic scale, microvessels are selectively heated and damaged, with minimal injury to the rest of the skin structures. However, for a hypertrophic or deep vascular lesion, such as many adult port-wine stains and venous malformations, much better efficacy is often obtained using the deeply penetrating 755 nm NIR alexandrite laser, as detailed by Izikson et al.[5] (Looking at Fig. 1.2, it is easy to observe that hemoglobin absorbs yellow light much more strongly than at 755 nm, a wavelength that is also well absorbed by melanin.) When alexandrite lasers are used for vascular lesion treatment, it is therefore imperative to use excellent skin cooling for epidermal protection as outlined by Chang and Nelson.[6]

Pearl 2

Selective photothermolysis allows microscopic laser surgery of histologic targets.

Pearl 3

Laser wavelength is usually the complementary color of the target chromophore (e.g., "red" 694-nm Q-switched ruby laser to treat green tattoos).

Pearl 4

Light penetration into skin increases with wavelength in the visible spectrum but decreases in the infrared.

Melanin absorbs across a wide spectrum of wavelengths. Eumelanin, the primary chromophore in the epidermis and darkly pigmented hair follicles, has a broad absorption spectrum spanning from ultraviolet light to the NIR region. Eumelanin is the chromophore targeted in lentigo simplex. It is also the target in laser hair removal with the secondary target being the follicular stem cells, as reported by Grossman et al.[7] In fair-skinned individuals with dark hair, wavelengths in the NIR range (810 nm diode; 755 nm alexandrite) are ideal for laser depilation. However, a common mistake is to use these popular devices for hair removal of red or blond hair, which is primarily composed of pheomelanin. These laser wavelengths are poorly absorbed by pheomelanin and are therefore ineffective for permanent removal of red or blond hair.

In general, water is not a useful target for SP because it is present at high concentration in almost every skin structure. Water absorption gradually increases starting in the NIR range and peaking within the mid-IR spectrum. When used in conjunction with appropriate epidermal cooling devices, lasers within this wavelength spectrum can function as nonablative modalities for photorejuvenation by targeting water within the dermis, thereby generating heat and controlled thermal damage. This wounding of the dermis subsequently results in collagen remodeling, as well as neocollagenesis,

contributing to the modest improvement in the appearance of rhytides.

NIR lasers have been reported by Sakamoto et al. and by Anderson et al. to target lipid-rich tissue. Unlike the targeting of traditional chromophores, which is based on electronic excitation of molecules, infrared lasers to target lipids are based on the vibrational modes of the molecules. At 1210 and 1720 nm, lipids have optical absorption slightly higher than that of water. Although there are no commercial devices yet available, the application of these forthcoming devices offers an appealing, alternative, noninvasive methodology of targeting lipids.

The second essential factor for SP is to use a pulse duration that allows heat to be confined during the laser pulse in or near the target structures. The moment that heat is formed in a target by preferential absorption of photons, the target begins to cool by conduction. Therefore heating of the target is a balance between the rate of photon absorption and the rate of cooling. The concept of a particular target's thermal relaxation time (TRT) is useful in clinical practice to pick the correct pulse duration. TRT is simply defined as the time required for substantial cooling of the target structure. TRT is strongly related to target size, and this variation accounts for the wide range of laser pulse durations needed for optimal dermatologic lasers. A simple and useful approximation is that TRT $\approx d^2$, when TRT is in units of seconds, and d is the target size in millimeters. For example, a 1-mm leg vein cools in approximately 1 second, whereas a 0.2-mm telangiectasia, typical for rosacea, cools in about 0.04 seconds (40 ms), and a 0.03-mm venule in a child's port-wine stain cools in approximately 0.001 seconds (1 ms). The optimal laser or IPL pulse duration is typically approximately equal to the TRT. In this example, a very long exposure from a low-power Potassium-titanyl-phospate (KTP) (532 nm) laser would be appropriate for treating the leg vein. A higher power KTP or pulsed dye (595 nm) laser operated at approximately 20 to 40 ms would be appropriate for the rosacea-associated telangiectasia, and a pulsed dye laser operated at approximately 1 ms would be appropriate for the pediatric port-wine stain. This extreme dependence of TRT on target size applies all the way down to the nanoscale of subcellular targets. Q-switched lasers are used in dermatology because their 10- to 100-ns pulse durations are shorter than the TRT for such targets as tattoo ink particles, melanosomes, and drug pigmentation deposits (see Case Study 1). Advances have resulted in the commercial availability of lasers capable of delivering pulses in the picosecond domain. Picosecond lasers have improved laser tattoo removal because the shorter pulse durations are even shorter than the TRT of very small tattoo ink particles. For example, tattoo ink particles are approximately 0.1 μm in size, thus they have a TRT of about 10 ns. One picosecond is equal to 10^{-12} seconds (0.001 ns). This pulse duration is much shorter than the TRT of tattoo ink particles, allowing picosecond pulse durations to destroy tattoo ink particles more selectively and at lower fluences. The concept of inertial confinement is similar to that of thermal confinement but involves pressure rather than temperature. Inertial confinement time (ICT) is defined by the time it takes a pressure wave to traverse the target structure, which is equal to d/v_a, where d is the target diameter, and v_a is the speed of

sound. In tissue the speed of sound is approximately 10^3 m/s. For a tattoo particle that is 0.1 μm diameter (10^{-7} m), the ICT is 10^{-10} seconds, or 100 ps. When a laser pulse is less than ICT, the target suffers extreme mechanical stress, which for tattoo ink particles tears them apart. Picosecond lasers tend to be more effective for tattoo removal than nanosecond lasers.

Pearl 5

Thermal relaxation time, which largely determines the ideal pulse duration for selective photothermolysis, in seconds is directly proportional to the square of the target size in millimeters.

Case Study 1

Pulse Width

A 26-year-old woman presented with severe scarring after "laser tattoo removal" performed in a local aesthetic parlor. She recalls she had laser hair removal performed by the same operator using the same machine with no side effects. However, this time her amateur black tattoo developed severe blistering, erythema, and edema immediately after treatment, followed by crusting and hypertrophic scarring. This irreversible complication resulted from use of an IPL, emitting millisecond pulses, rather than the appropriate nanosecond or picosecond lasers that can remove tattoos without scarring.

The matching of TRT and pulse duration is clinically important to achieve efficacy, avoid side effects, and even to define the targets that will respond. For example, consider a young man with both nevus of Ota and a dark beard on his face. Both the nevus and his beard hair contain high concentrations of the same chromophore, melanin. A Q-switched alexandrite laser (approximately 755 nm wavelength) will be highly effective for fading his nevus of Ota because the targets are small, isolated melanocytes scattered deeply throughout his dermis. The appropriate end point is immediate whitening, due to microscopic gas bubbles formed when the target melanocytes in his dermis are fractured. However, this Q-switched alexandrite laser will not permanently remove his hair because its pulse duration is a million times shorter than the TRT for a terminal hair follicle. This laser merely vaporizes the hair shaft (which is already dead) before heat can flow to the hair follicle epithelium, and the patient can be informed with confidence that his beard will not be accidentally removed. In contrast, a long-pulse (3 to 30 ms) alexandrite laser *at the identical wavelength* could permanently remove his beard without affecting his nevus of Ota. This long pulse duration is usually incapable of providing thermal confinement in something as small as an isolated melanocyte but allows plenty of time for heating of the entire hair follicle without vaporizing its pigmented hair shaft. However, in case of high concentration of melanocytes in the dermis on a nevus of Ota (e.g., darker lesions), it could potentially create a bulk heating and accidental dermal burn.

A common professional liability issue related to pulse duration is the use of

long-pulsed sources, such as IPLs, broadly available for laser hair removal, for the treatment of tattoos. Long-pulsed lasers and IPLs emit millisecond domain pulses that heat the tattooed skin at large instead of the individual ink particles because the pulse duration greatly exceeds the TRT of the ink particle. The surrounding dermis is therefore heated, causing unselective thermal damage, blistering, dyschromia, and scarring, as reported by Wenzel et al.[8] Unfortunately, similar mistakes are commonly observed due to the lack of a full understanding of SP and incorrect choice of treatment pulse width.

The third factor for optimal SP is sufficient fluence to affect the targets. In general, the fluence necessary is inversely related to absorption by the target structures—stronger absorption requires lower fluence, and vice versa. This is the reason, for example, that a typical alexandrite laser fluence for treatment of a port-wine stain (see Case Study 2) is 40 J/cm^2, whereas that for pulsed dye laser treatment of the same lesion may be only 8 J/cm^2.

Case Study 2

Depth of Wavelength Penetration

A 6-year-old child with Sturge-Weber syndrome has a large port-wine stain on her arm. She has been treated with a 595-nm pulsed dye laser, but after 10 sessions the lesion seems unresponsive to treatment. Another dermatologist starts treatment with a 755-nm long-pulse alexandrite laser and, unlike the previous treatment, the lesion seems to respond quite well. Most port-wine stains are malformations of small venules and can extend into the deep dermis and underlying structures. Pulsed dye lasers at 595 nm are also excellent for SP of the upper dermis; this yellow wavelength does not penetrate well into deeper tissues. The alexandrite laser at 755 nm penetrates much deeper and corresponds to the wavelength of an absorption band of deoxyhemoglobin, which is present in the lesion's venules. Switching from pulsed dye or KTP lasers, to alexandrite lasers is useful for treating the deeper portions of port-wine stains. Care must be taken to avoid bulk heating and to treat at fluences near the threshold for selective vascular injury.

For pulsed sources, pulse repetition rate is one of the treatment parameters. Pulse repetition rate is the frequency at which laser pulses are emitted and is measured in hertz (Hz), where 1 Hz is 1 pulse/second. It is useful to use higher repetition rates for treatments that require a large number of laser pulses (e.g., large tattoos). Although it is tedious to treat a large tattoo using 1 pulse/second, increasing the frequency of pulses makes the treatment less time consuming (and more challenging to distribute the pulses uniformly).

Skin cooling: limiting thermal damage to the intended targets

Sparing of the epidermis and superficial dermis is important for selective destruction of deeper structures and can be improved by the use of appropriate

skin cooling. Cooling can be applied before (precooling), during (parallel cooling), and after the laser pulse (postcooling). Similarly to laser-induced tissue heating, cooling should be applied keeping in mind the histological target. According to Zenzie et al., the greater the depth of an anatomic structure, the longer the cooling should be applied. For epidermal protection, Sakamoto et al. reported that 20 to 50 ms is enough, whereas for epidermal and dermal protection (e.g., for targeting subcutaneous fat) cooling should be applied for 5 to 10 seconds. Cooling can be applied using direct solid contact cooling (e.g., cold sapphire window), automated cryogen spray (direct cooling devices [DCDs]) or by blowing direct cold air. Cold-air cooling has the advantage of bulk skin cooling, which limits pain, edema, and the risk of burns from residual heat.

For the choice of proper dosimetry, it is crucial to be familiar with the particular device being used and to carefully observe skin response to treatment. The combination of laser wavelength, pulse duration, spot size, skin cooling, and dosimetry can suggest initial treatment parameters, but only careful observation of immediate clinical end points will ensure efficacy (Figs. 1.3 to 1.5), helping to avoid side effects. Common clinical end points are summarized in Table 1.1.

Pearl 6

Cooling is very helpful to protect the epidermis and superficial dermis during selective photothermolysis.

Pearl 7

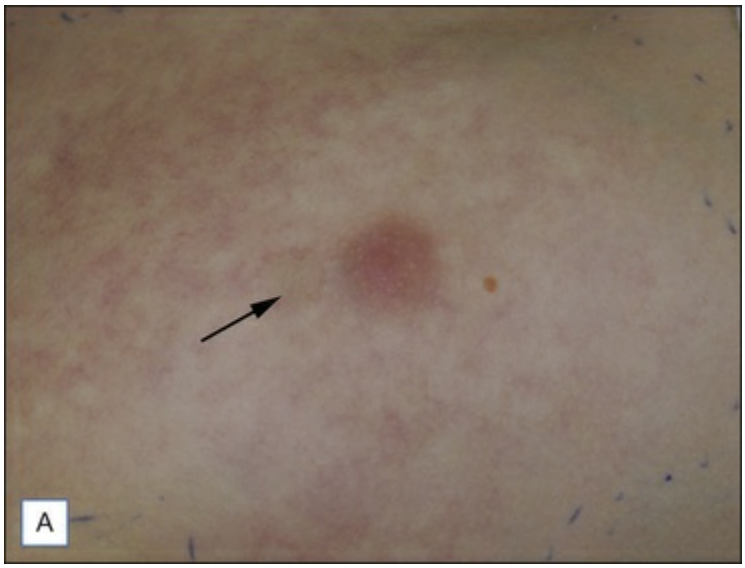
Careful examination of immediate skin end points can help in choosing laser parameters.

Pearl 8

Side effects are usually a consequence of poor choice of light source and parameters.



FIGURE 1.3 Expected clinical end point after laser treatment of pigmented lesions, using a Q-switched 755-nm alexandrite laser for solar lentigines. Immediate response observed with epidermal whitening due to steam bubbles.



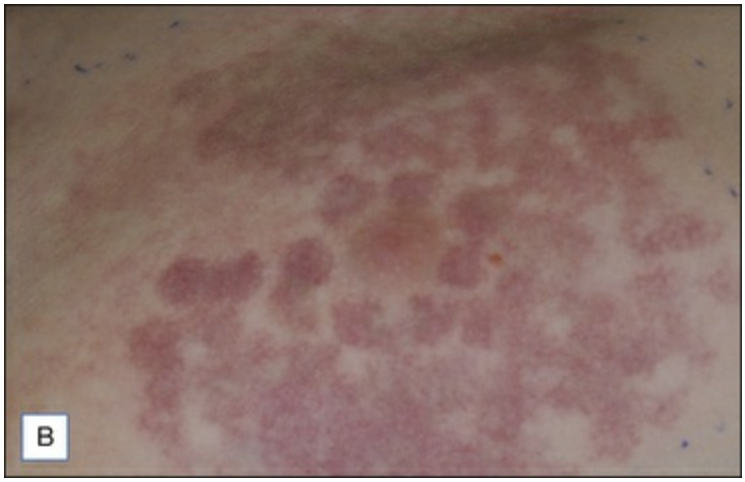


FIGURE 1.4 Expected clinical end point after laser treatment of a vascular lesion: (**A**) Child's chest with port-wine stain previously treated with laser, before pulsed dye laser (PDL) session, with immediate response after a single 585-nm PDL pulse, 3 ms pulse width, 6 mm spot size, 9 J/cm^2 with dynamic cooling *(arrow)*. (**B**) Note immediate round-shaped purpura where laser is applied, indicating vessel coagulation.





FIGURE 1.5 Expected clinical end point after laser treatment of a vascular lesion: (**A**) Wrist with port-wine stain. (**B**) Immediate response after a single *(arrow)* 755-nm alexandrite laser pulse, 1.5 ms pulse width, 6 mm spot size, 80 J/cm^2 with dynamic cooling. Note immediate bluish-gray color, indicating vessel coagulation.

Table 1.1

Most common laser types used in dermatology

Primary chromophores	Lasers	Wavelength (nm)	Mode/pulse width range	Typical applications	Expected clinical end points	Unwanted end points
Proteins, DNA	Excimer	308	QCW (ns pulses)	UVB phototherapy of psoriasis; vitiligo; atopic dermatitis	Nonselective damage with erythema, mild edema	—
Hemoglobin	Pulsed dye (yellow)	577–600	Pulsed 0.45–1.5 ms; 3–40 ms stuttered	Especially PWS; telangiectasia; warts; red scars; mild photodamage	Purpura, durable vessel darkening, vessel disappearance, selective coagulation	Selective photothermoly should NEVER present: ablatio uniform gray coagulation, positive Nikols sign, shrinkage or darkening o normal skin (e. chrysiasis)
Hemoglobin, melanin	KTP	532	QCW, CW, or pulsed	Telangiectasia; benign lentigo; warts		
Melanin, hemoglobin, water (weak)	Xenon flashlamp (IPL)	500–1200	Pulsed 2–50 ms; 20–100 ms stuttered or single pulse	Telangiectasia; mild photodamage; hair removal; benign lentigo	Subtle darkening of pigmented lesions, vessel disappearance	
Melanin, hemoglobin (weak)	Long-pulsed alexandrite	755	Pulsed 1.5–40.0 ms stuttered	Hair removal; leg veins; hypertrophic PWS	Perifollicular erythema, edema at 5 min	
Melanin	Long-pulsed ruby	694	Pulsed 3 ms; 100 ms stuttered	Hair removal; some nevi		
Melanin	Diode	800	Pulsed 5–500 ms	Hair removal; venous lakes, telangiectasias, leg veins		
Melanin	Long-pulsed Nd:YAG	1064	Pulsed or stuttered, 3–100 ms	Hair removal in dark skin; leg veins		

Melanin and tattoos	Q-switched Nd:YAG	532 1064	Q-switched 5-10 ns	532: Epidermal pigment; red tattoos 1064: Epidermal/dermal pigment (lentigines, nevus of Ota, etc.); tattoos (black 1064, red 532)	Immediate whitening	
Melanin and tattoos (except red)	Q-switched ruby	694	Q-switched 20 ns	Epidermal/dermal pigment; lentigines, nevus of Ota; tattoos (black, blue, green)		
Melanin and tattoos (except red)	Q-switched alexandrite	755	Q-switched 50-100 ns	Epidermal/dermal pigment; lentigines, nevus of Ota; tattoos (black, blue, green)		
Melanin and tattoos (except red)	Picosecond alexandrite	755	750 ps	Tattoos (black, blue, green)		
Tattoos	Picosecond Nd:YAG	532 1064	750 ps	532: red tattoos 1064: tattoos (black 1064, red 532)		
Water	Mid-IR Nd:YAG	1320	Pulsed 20–50 ms stuttered macropulses	Nonablative dermal remodeling	Nonselective damage: erythema, edema, sometimes pinpoint bleeding	—
Water	Mid-IR diode	1450	Pulsed 5–260 ms	Nonablative dermal remodeling, fractional resurfacing		
Water	Erbium:glass	1540	Pulsed 1–10 ms	Nonablative dermal remodeling, acne, fractional resurfacing	—	—
Water	Thulium:YAG	1927	Pulsed 10 ms	Nonablative/ablative dermal remodeling, acne, fractional resurfacing		
Water	Erbium:YAG	2940	Pulsed 0.1–3 ms	Ablation of epidermal lesions; skin resurfacing; ablative fractional resurfacing		
Water	CO_2	10,600	CW, scanned or pulsed/1 μs–1 ms	Ablation of lesions; resurfacing for moderate–severe photodamage; rhytides; scars, ablative fractional resurfacing		

CW, continuous wave; *IPL*, intense pulsed light; *PDL*, pulsed dye laser; *pulsed*, high-energy pulses; *PWS*, port-wine stain; *QCW*, quasi-continuous wave (a rapid low-energy pulse train); *SP*, selective photothermolysis.

Fractional photothermolysis

FP uses microbeams of laser light to target tissue, inducing microthermal zones (MTZs) of injury, as reported by Manstein et al.[2] Each MTZ is typically 100 to 300 μm in diameter. The depth and density (number per unit area) of the microlaser beams applied to the tissue can be adjusted depending on the

clinical indication. The advantage of this technique is that it spares untreated skin surrounding each MTZ, allowing fast healing and reducing the risk of side effects. A typical FP treatment session provides laser exposure to approximately 10% to 50% of the skin.

Soon after its introduction in 2004 the concept of FP has been widely embraced in dermatology. A number of new devices, laser wavelengths, and clinical indications have been developed with success. In principle, FP can be applied with a wide variety of energy sources capable of producing an array of small zones of skin damage. These include various nonablative NIR lasers (1320 to 1550 nm; 1927 nm thulium) and ablative lasers (2940 nm Er:YAG; 10,600 nm CO_2). Currently, even visible light and other technologies, such as ultrasound and radiofrequency (RF) devices, have been using fractionated applicators. Photoaging and pigmentary alterations, scar treatment, melasma, striae, and xanthelasma are examples of the variety of clinical indications that can be treated with FP (see respectively the studies by Manstein et al., Alster et al., Tannous & Astner, Kim et al., and Katz et al.).

Interestingly, in addition to local thermal destruction and stimulation, fractionated devices may also play an important role for drug delivery into the tissue and for extruding material out of the skin, as in the studies by Haedersdal et al. This has also been reported by Ibrahimi et al. using an ablative fractionated Er:YAG laser to treat an allergic tattoo reaction with success. Whereas conventional treatment of allergic tattoo reactions with a Q-switched laser alone would likely increase immunogenicity of the tattoo pigment post treatment and the risk of a systemic allergic response, the ablative fractional laser has shown the ability to remove allergic tattoo pigment as an alternative method without inducing a systemic allergic reaction.

Pearl 9

Fractional photothermolysis can be performed with ablative and nonablative energy sources.

Other energy-based technologies

New non-light-based devices have been developed for medical use, including intense focused ultrasound (IFU), RF, and cryolipolysis.

IFU waves can also be used to cause thermal damage and resultant tissue contraction. These nonlaser energy-based devices are not chromophore selective. Ultrasound waves, as a treatment tool, can be focused to deliver pulses of energy into any depth but are mostly used to target deep dermis and superficial fascia or to destroy fat. The focused energy causes discrete, well-defined areas of thermal damage that undergo contraction. This technology has been used for tissue tightening and can also be applied to destroy skin lesions.

IFU devices deliver ultrasound waves longitudinally to a focal target point at a selected depth in the dermis or superficial fascia. The present commercially available devices for dermatology provide a maximum focal depth of

approximately 4.5 mm. During the procedure, diagnostic ultrasound imaging is simultaneously used, which enables more exact placement of the pulses in the correct tissue planes with avoidance of nerves and vascular structures. Pulses delivered are in the millisecond domain and result in zones of thermal damage that undergo contraction resulting in tissue tightening.

RF devices nonselectively heat local areas of tissue through delivery of a rapidly alternating direct electric current through the skin. The damage caused by RF devices ideally results in partial denaturation of type I collagen. Collagen subsequently undergoes remodeling and repair through the synthesis of new collagen, theoretically resulting in tightening of the treated area. RF devices are used in dermatology to achieve tightening of tissue in areas of laxity. RF devices that destroy adipose tissue in the same manner are also commercially available.

RF devices operate at frequencies similar to radio bands and deliver a rapidly alternating electric current that heats tissue. These devices are nonselective, but the pattern of heating can be controlled to some extent by geometric arrangement of the electrode(s) in contact with the skin and by local changes in electrical impedance. The local energy deposited by RF inside tissue is proportional to the density of the current squared, multiplied by the impedance of the tissue medium. These devices can be unipolar, bipolar, or multipolar, and energy can be delivered from electrodes held on or in close proximity to the skin surface or via invasive microneedles.

Both RF devices and IFU devices have been used in a fractional manner to destroy tissue, similarly to the fractional laser devices.

An innovation for the noninvasive reduction of unwanted fat occurred in 2008 when Manstein et al. showed that areas of unwanted fat could be eliminated by freezing without damage to the surrounding tissue, a concept termed cryolipolysis. Cryolipolysis uses the concept of selective destruction. Lipids in adipose tissue freeze at a higher temperature than water. The use of cold at specific temperatures can effectively induce a cold panniculitis, resulting in apoptosis of adipocytes with sparing of other cutaneous structures. Cryolipolysis is now a widely used procedure for selective, noninvasive removal of unwanted fat.

Cryolipolysis extracts thermal energy in a controlled manner through cooling and is based on the observation that lipids freeze at a higher temperature than water.[9] "Popsicle panniculitis," or cold panniculitis, occurs in infants and was initially described in 1970 when an infant sucking on a popsicle developed an indurated nodule on the cheek, resulting in transient necrosis.[10] Future applications of this concept may be used to treat lipid-rich skin lesions.

Photobiostimulation or low-level light therapy (LLLT) has been approved for the treatment of androgenetic alopecia using low-power continuous lasers in the milliwatt range at wavelengths of approximately 630 to 850 nm. Photobiomodulation has been suggested to work by stimulation of mitochondrial signaling.

Pearl 10

IFU devices use longitudinal sound waves to cause fractional zones of thermal damage, resulting in tissue tightening or destruction of targets.

RF devices deliver heat via an electric current causing nonselective denaturation of collagen followed by collagen repair and remodeling resulting in tissue tightening.

Cryolipolysis selectively targets adipose tissue for apoptotic destruction by extraction of heat through cooling.

Conclusion

Lasers, other light sources, other energy sources, and tissue cooling technology will continue to evolve into unforeseen applications. Many interesting, fundamental, and clinically important questions remain to be answered about energy-based treatments in dermatology.

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2

Laser treatment of vascular lesions

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Summary and Key Features

- Vascular lesions are among the most common indications for laser treatment.
- Treatment relies on the theory of selective photothermolysis and aims to confine thermal injury to targeted vessels.
- Pulsed dye laser (PDL) is the treatment of choice for port-wine stains, but multiple vascular targeting devices can be used. Early treatment is thought to enhance response. Resistant or hypertrophic lesions can be treated with an alexandrite laser.
- Congenital or infantile hemangiomas can also be treated with laser. Combined treatment with β-blockers should be considered. Indications for laser treatment include ulcerated lesions and involuted lesions with residual telangiectasias and/or textural change. Laser treatment may be indicated for some proliferative lesions as well.
- Erythema and telangiectasias associated with rosacea may be treated with vascular targeting light sources, including the PDL or intense pulsed light.

Introduction and history

The treatment of vascular lesions was among the first applications of lasers in dermatology. Laser surgery has since become the treatment of choice for many vascular lesions, including port-wine stains (PWSs), hemangiomas, rosacea, and poikiloderma.

Vascular-specific lasers have evolved considerably since the original continuous wave lasers. The 1960s saw the emergence of ruby and argon lasers, which improved the color of PWSs and hemangiomas, but their relatively nonspecific heating of the skin resulted in unacceptably high rates of scarring and pigmentary change. In 1983 the theory of selective photothermolysis proposed a way to confine thermal injury to the target of interest while minimizing collateral damage to surrounding tissue.

Three components are necessary for selective photothermolysis: a laser wavelength with preferential absorption of the target chromophore, appropriate pulse duration matched to the target size, and a fluence that both treats the target and minimizes nonspecific thermal injury. Thermal relaxation time is defined as the time needed for the heated target to cool halfway to its initial temperature. The ideal pulse duration is shorter than or equal to the thermal relaxation time of the target. A pulse duration that is too short may not be effective, whereas one that is too long may cause heat to dissipate to surrounding structures and cause unwanted thermal injury. The classic target chromophore for vascular lesions has been oxyhemoglobin, which has the greatest absorption peaks at 418, 542, and 577 nm (Fig. 2.1). The laser light is absorbed by oxyhemoglobin and converted to heat, which is transferred to the vessel wall, causing coagulation and vessel closure. Other hemoglobin species have more recently been recognized as appropriate targets, depending on the vascular lesion. For example, venous lesions may benefit from wavelengths of light that target deoxyhemoglobin. The alexandrite laser at 755 nm is close to a deoxyhemoglobin absorption peak and has been used for refractory or hypertrophic PWSs, venocapillary malformations and venous lakes. Methemoglobin[1] absorption (which forms after 585 or 595 nm treatment at or above 5 J/cm^2) has been recognized as another potential target chromophore.

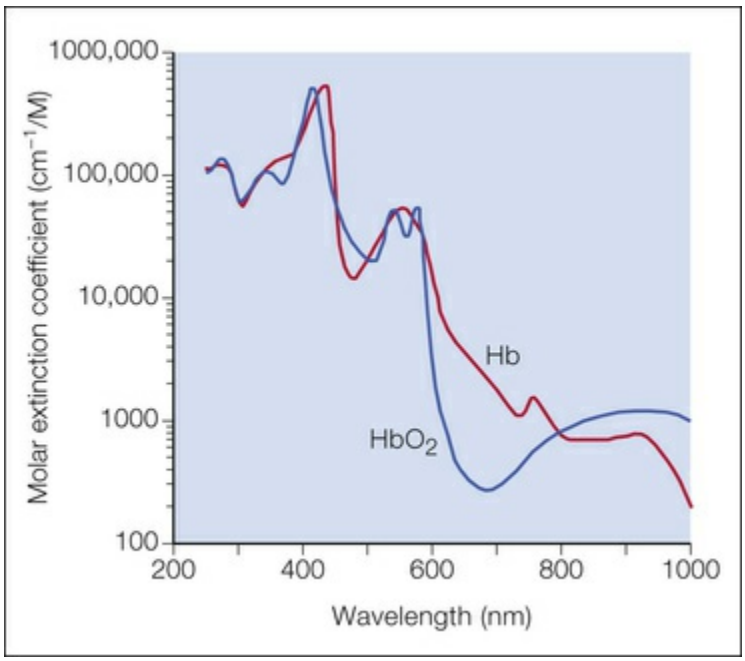


FIGURE 2.1 Optical absorption of hemoglobin. Source: Dr Scott Prahl, http://omlc.ogi.edu/spectra/hemoglobin.

The pulsed dye laser (PDL) became available in 1986 and was initially developed at 577 nm to target the yellow absorption peak of oxyhemoglobin. It was later realized that, for selective photothermolysis to occur, the laser wavelength did not have to be at an absorption peak for the target chromophore as long as preferential absorption still occurred. PDLs shifted to 585 nm, allowing for a depth of penetration of approximately 1.16 mm; 595 nm PDLs later became available to achieve greater depth of penetration. PDLs have also evolved to incorporate longer pulse durations. Early PDLs had a fixed pulse duration of 0.45 ms, whereas currently available PDLs have pulse durations from 0.45 to 40 ms. Longer pulse durations have the advantage of treating the target without causing purpura.

Epidermal cooling was introduced in the 1990s as a means to protect the epidermis, minimizing pigmentary changes and scarring. Cooling also permits the use of higher fluences and thus provides greater treatment efficacy. In addition, cooling minimizes discomfort associated with treatment. Modern cooling devices include dynamic spray, contact, and forced cold air.

Because the PDL reaches a depth of only 1 to 2 mm, other lasers have been developed to treat vascular lesions in an attempt to achieve a greater depth. For example, the alexandrite laser at 755 nm and neodymium:yttrium-aluminum-garnet (Nd:YAG) laser at 1064 nm penetrate up to 50% to 75% deeper into the skin. Given that the absolute absorption of hemoglobin is lower at these wavelengths, higher fluences are required.

Intense pulsed-light (IPL) devices emit polychromatic noncoherent broadband light from 420 to 1400 nm with varying pulse durations. Filters are implemented to remove unwanted shorter wavelengths, to treat vascular lesions with blue-green to yellow wavelengths.

Other vascular lasers and light sources include potassium titanyl phosphate (KTP) (532 nm), other near-infrared, long-pulsed lasers, such as diode (800 to 810 nm, 940 nm), and dual wavelength lasers, such as PDL combined with Nd:YAG (595 nm and 1064 nm).

Vascular anomalies classification

The International Society for the Study of Vascular Anomalies (ISSVA) publishes a widely accepted standard for classification of vascular anomalies that was updated in 2014. Lesions are broadly grouped as either vascular tumors, characterized by a proliferation of blood vessels, or vascular malformations, characterized by vessels with abnormal structure. Hemangioma, a type of vascular tumor, and PWS, a type of vascular malformation, are the most common vascular anomalies that present for laser treatment (Table 2.1). Of note, certain rare lesions seem to defy precise classification under these terms and have been listed in a provisional category.

Table 2.1

Comparison of infantile hemangioma and port-wine stain

	Infantile hemangioma	Port-wine stain
Onset	• First few weeks of life • Precursor may be present at birth	• Present at birth
Course	• Proliferative period in first year of life, followed by slow involution	• Does not regress • May become hypertrophic, more violaceous with age • May develop vascular blebs
Tissue marker	• GLUT1 positive	• GLUT1 negative

GLUT1, Glucose Transporter 1.

Port-wine stains

Overview

PWSs are vascular malformations that are composed of ectatic capillaries and postcapillary venules in the superficial vascular plexus. PWS vessels are characterized by diminished vascular tone and decreased density of nerves, especially those with autonomic function. In most cases, PWSs are congenital, although in rare cases they may be acquired. PWSs are found in approximately 0.3% of newborns. They tend to occur on the head and neck but may appear anywhere on the body. PWSs persist throughout life and many thicken with time (Fig. 2.2). The mean age of hypertrophy has been reported as 37 years, and by the fifth decade approximately 65% of lesions may become hypertrophied or nodular. There may be associated soft tissue overgrowth, leading to functional impairment in such areas as the lip or eyelid. Vascular blebs often form and may bleed with minimal trauma. These lesions are often considered disfiguring, prompting many patients to seek treatment. PWS vessels vary in size from 7 to 300 μm, with older patients tending to have larger vessels.



FIGURE 2.2 **A, B** Hypertrophic port-wine stain not yet treated.

PWSs can be associated with various syndromes. Sturge-Weber syndrome involves a facial PWS and may have associated eye and neurologic abnormalities, including glaucoma, seizures, and developmental delay. Traditionally this was mainly attributed to PWS in the ophthalmic distribution

of the trigeminal nerve. However, studies have suggested several other distributions are possible in Sturge-Weber syndrome and may reflect patterns of somatic mosaicism. In recent years, both isolated PWSs and Sturge-Weber syndrome have been associated with a somatic activating mutation in the gene encoding guanine nucleotide-binding protein G(q) subunit alpha (GNAQ), as detailed in a seminal paper by Shirley et al. Another syndrome, Klippel-Trénaunay, involves PWSs on an extremity associated with limb hypertrophy and lymphatic malformations. PWSs can also occur in association with arteriovenous malformations in capillary malformation–arteriovenous malformation syndrome.

Treatment

Goals of treatment of PWSs include decreasing redness, reducing psychosocial distress, and preventing development of blebs that may bleed or become infected. In addition, it has been theorized that treating PWSs early may minimize hypertrophy later in life.

Despite the overall effectiveness of PDL, individual patient response is variable. Approximately 80% of treated patients see a successful decrease in redness or thickness, but only approximately 20% will clear completely. One study found predictors of improved response include small size (less than 20 cm^2), location over bony areas, in particular the central forehead, and early treatment. Another study in 49 infants who started laser treatment before 6 months of age demonstrated an impressive average clearance of 88.6% after 1 year. Early treatment may be more beneficial due to thinner and overall smaller lesions, as well as the presence of hemoglobin F (a type of hemoglobin present during gestation and the first year of life) and less dramatically dilated vessels in infants. PWSs may darken again after laser therapy, a phenomenon dubbed "redarkening." Still, redarkened areas remain lighter than their original untreated color.

Treatments are typically performed at 3-6 week intervals, and it is not uncommon for 10 or more treatments to be performed initially, until a plateau is reached or the lesion clears (Fig. 2.3). In choosing settings, it is advisable to determine the fluence threshold on the darkest portion of the PWS with one or two test pulses before treating the entire lesion. The fluence is adjusted to achieve the desired end point, which in the case of PDL is immediate purpura. If instead a gray color appears, the fluence is too high. Careful monitoring for tissue response is essential.



FIGURE 2.3 Port-wine stain: (**A**) before and (**B**) after PDL treatments.

Changing the pulse duration may allow targeting of different sizes of vessels. The ideal pulse duration for PWS treatment has been proposed at 1 to 10 ms. In practice, treatment often begins at 1.5 ms. Parameters to consider include 7- to 10-mm spot size, pulse duration of 0.45 to 6 ms, with appropriate epidermal cooling, such as cryogen spray cooling of 30 ms with a 20-30 ms delay. Longer pulse durations may be considered in darker skin types. Treatment should start at a lower energy that can be increased as tolerated. Parameters will vary by device.

As with any laser treatment, complications of PDL may include pigmentary change. When treating darker skin types, the risk of hypopigmentation and hyperpigmentation can be minimized by using appropriate cooling and longer pulse durations. Treatment intervals may need to be longer to allow for any pigmentation changes to resolve before proceeding with additional treatment. Care must be taken with leg lesions, which are prone to hyperpigmentation.

Alexandrite laser is typically used for PDL-resistant lesions, although it may be implemented as a first-line treatment for more hypertrophic, violaceous PWS in adults (Fig. 2.4). The desired end point in this case is a transient gray color that evolves into a deeper persistent purpura over several minutes, as described by Izikson and Anderson in 2009. Care must be taken not to overlap or "stack" pulses because scarring can occur. Notably, the range of appropriate fluences for alexandrite laser is quite broad.



FIGURE 2.4 Violaceous, hypertrophic port-wine stain: (**A**) before and (**B**) after alexandrite laser treatments. Note improvement in color and thickness. Courtesy of Dr. R. Rox Anderson.

Nd:YAG laser and combined 595 nm and 1064 nm lasers can also be used for PWSs. Although depth of penetration can be increased, there is a narrow therapeutic window with these devices, and caution is advised to avoid scarring. These devices should only be used by experienced laser surgeons.

IPL with appropriate vascular filters can also be used, and studies have been able to tune the IPL to optimize the wavelength range for PWS. As with many lasers, treatment in hair-bearing areas may lead to permanent hair loss. The risk is greater on the eyelashes, given the proximity of follicles to the surface, and on the eyebrows and scalp of young children, particularly those of darker skin types. Hair loss can also occur with long pulsed laser treatment of vascular lesions.

Nodules or blebs within PWS can be treated with excision or laser. In the case of PDL, several pulses or intentionally stacked pulses may be required. Given the limited depth of penetration of PDL, deeper penetrating lasers, such as alexandrite or Nd:YAG, can be used or nodules can be ablated with the carbon dioxide (CO_2), and erbium-doped yttrium-aluminum-garnet (Er:YAG) lasers.

Photodynamic therapy (PDT) has been used with some success but is limited by the administration of systemic hematoporphyrin photosensitizers, which result in prolonged photosensitivity over weeks. Alternative photosensitizers, such as benzoporphyrin-derivative monoacid ring A and mono-L-aspartyl chlorin e6 (Npe6), have shorter periods of photosensitivity and may offer promising alternatives. PDT may potentially be a useful treatment if parameters can be optimized or combined with PDL.

Recent research has sought to improve treatment efficacy by combining light-based removal of PWSs with posttreatment antiangiogenic agents, especially

rapamycin. Improved results are attributed to rapamycin's inhibition of pathways that are normally activated by laser-induced vessel damage. Although some studies on topical rapamycin for other dermatologic conditions have found no evidence of systemic absorption, some studies using it for PWSs have found a nominal but not clinically significant amount absorbed.

Laser speckle imaging (LSI) and laser-Doppler imaging (LDI) have offered noninvasive ways to measure response to treatment by quantifying capillary perfusion and blood flow dynamics intraoperatively. Such technologies may offer an objective way to assess if treatment is adequate and in the future could be used to guide physicians to providing improved results.

Pearl 1

Outline borders of PWSs prior to treatment.

Laser pulses can induce erythema that blurs the border, making it difficult to appreciate the appropriate area to target. Prior to treatment with yellow light lasers, such as the PDL, the edges of the lesion may be outlined with a yellow highlighter to facilitate consistent visualization of the area of interest.

Infantile hemangiomas

Overview

Infantile hemangiomas are benign endothelial cell proliferations that represent the most common tumor of infancy, occurring in 4% to 10% of infants. Female gender is a notable association, with lesions arising three times as often in female infants. Other risk factors include prematurity, multiple gestation, advanced maternal age, and family history of hemangiomas. The relative significance of these risk factors remains under study, and a prospective cohort study on infantile hemangiomas in twins suggested the cause is multifactorial. They have been theorized to originate from embolized placental stem cells or as a response to tissue hypoxia. Expression of Glucose Transporter 1 (GLUT 1), a fetal-type endothelial glucose transporter, distinguishes them histologically from other vascular tumors and vascular malformations. Hemangiomas may be characterized as localized or segmental and as superficial (clinically red), deep (clinically blue or skin-colored), or mixed. Typical presentation is within the first few weeks of age as a whitish, red, or telangiectatic macule, with 60% arising on the head and neck.

The proliferative period typically lasts until 6 to 8 months for superficial hemangiomas, although deep hemangiomas may proliferate longer. Involution then occurs more slowly over years. An often-cited estimation is that approximately 10% of hemangiomas are expected to regress with each year of age, with the vast majority having regressed by age 10, although studies suggest this process may occur sooner. After regression, many hemangiomas leave behind residual fibrofatty tissue, atrophy, or telangiectasias.

Hemangiomas typically do not require imaging studies. Multiple

hemangiomas, usually greater than five, or hemangiomas in certain locations, may prompt radiologic investigation to assess for possible associated syndromes or visceral involvement. PHACES syndrome must be considered in large segmental facial hemangiomas and is characterized by *P*osterior fossa malformations, *H*emangiomas, *A*rterial anomalies, *C*oarctation of the aorta, *E*ye abnormalities, and *S*ternal or supraumbilical raphe. The presence of characteristic perineal or lumbar hemangiomas may prompt evaluation for related syndromes, such as *P*erineal hemangioma, *E*xternal genital malformations, *L*ipomyelomeningocele, *V*esicorenal abnormalities, *I*mperforate anus, and *S*kin tags (PELVIS) or *L*ower body hemangioma, *U*rogenital anomalies or ulceration, *M*yelopathy, *B*ony deformities, *A*norectal malformations and arterial anomalies, and *R*enal anomalies (LUMBAR). Diffuse neonatal hemangiomatosis involves multiple skin hemangiomas and signifies a risk of visceral hemangiomas, most commonly liver followed by the gastrointestinal tract.

Two rare types of hemangiomas that are present at birth and are GLUT1-negative include noninvoluting congenital hemangiomas (NICHs) and rapidly involuting congenital hemangiomas (RICHs). A category of partially involuting congenital hemangiomas has been described in which lesions begin to regress but then plateau and persist.

Treatment

Treatment of hemangiomas is indicated for functional impairment, as well as for such complications as ulceration, infection, or bleeding. Hemangiomas can cause functional difficulties when critical anatomic structures are affected, including airway compromise, symptomatic hepatic involvement, visual obstruction, or auditory canal obstruction.

The historic treatment for many hemangiomas, in the absence of functional difficulties or complications, has been watchful waiting, also called active nonintervention. More recently, it has been recognized that an indication for treatment is prevention of long-term scarring and associated psychosocial distress, especially when lesions involve cosmetically sensitive areas.

Topical treatments are most useful for superficial hemangiomas. Timolol has emerged as the preferred topical option and is a less aggressive alternative to propranolol, discussed later. In a randomized controlled trial, timolol plus PDL was superior to PDL alone in effecting resolution of infantile hemangiomas. Laser options are discussed in further detail below. Other topical therapies include high-potency topical corticosteroids, imiquimod (although effectiveness of this agent is somewhat controversial), and becaplermin gel (a recombinant platelet-derived growth factor, used for healing of ulcerated lesions). Ulcerated lesions may also be supportively treated with local wound care using barrier creams and occlusive dressings.

Systemic treatment may be indicated for ulcerated, functionally problematic, or disfiguring lesions. Oral propranolol has been established as a safe and effective treatment and has replaced oral corticosteroids as the preferred first-

line therapy for infantile hemangiomas. In a meta-analysis, propranolol showed superior reduction in hemangioma size compared with observation, placebo, and oral corticosteroids. A recent randomized controlled trial on 460 infants, among the largest studies to date, showed propranolol to be effective to date, showed propranolol to be effective when given for 6 months. Its mechanism remains unclear and has been speculated to involve promotion of pericyte-mediated vasoconstriction, inhibition of vasculogenesis and catecholamine-mediated angiogenesis, and inactivation of the renin-angiotensin system. Although propranolol is generally well tolerated, infrequent adverse effects include hypoglycemia, bronchospasm, hyperkalemia, hypotension, and bradycardia. Please end sentence at bradycardia.

Laser treatment is most effective for superficial hemangiomas, given the laser light's limited depth of penetration. For mixed superficial and deep lesions, PDL may be implemented to lighten the color, though it will not affect the deeper component. Studies suggest early treatment with laser, especially PDL, may halt further growth and facilitate a transition to the plateau or involution phase with minimal adverse effects. Laser treatment may also be beneficial for hemangiomas in areas prone to ulceration, specifically the anogenital area. A study on 78 patients with ulcerated hemangiomas showed that 91% improved after a mean of two PDL treatments.

A range of fluences has been used for PDL treatment of proliferating hemangiomas. In our opinion, although proliferating lesions can definitely benefit from laser treatment, there is a risk of ulceration with treatment and low fluences should be used. Treatment settings to consider for PDL include pulse duration 0.45 to 1.5 ms, 10 or 7 mm spot, fluence 5-7 J/cm^2, and appropriate cooling. Lower fluences and longer pulse durations are advisable in darker skin types. Parameters vary by device. Multiple treatments are generally required and may be performed at 2-week intervals for rapidly proliferating lesions or 4- to 6-week intervals for involuting lesions. The main risks of treatment are ulceration and scarring, as well as hypopigmentation. There have been rare reports of serious bleeding after PDL treatment for hemangiomas, primarily with older lasers without cooling, and one case with a 595-nm laser with cooling, using relatively high fluences.

The KTP laser and IPL have also been implemented to successfully treat hemangiomas. Some have used the Nd:YAG laser for hemangiomas to get greater depth of penetration. Extreme caution is required because there is a narrow therapeutic window for Nd :YAG treatment and significant ulceration and scarring can easily occur.

After involution, hemangiomas can leave behind telangiectasias or residual fibrofatty tissue. Telangiectasias can be treated with the PDL (Fig 2.5), and texture changes have been shown to improve with ablative (Fig 2.6) or nonablative fractional resurfacing.

Pearl 2

1. Consider all available treatment options.

Combining β-blockers with laser may achieve faster and more complete resolution of infantile hemangiomas.

2. Consider the depth of an infantile hemangioma in choosing the appropriate treatment.

Timolol is effective for superficial lesions but may not produce much improvement in lesions with a deeper component. For deeper lesions, propranolol may be appropriate.





FIGURE 2.5 Involuted hemangioma before and after pulsed dye laser treatments.





FIGURE 2.6 Involuted hemangioma before and after pulsed dye laser treatments to improve the erythema and telangiectasias, and fractionated CO_2 laser treatments to improve the texture and reduce fibrofatty tissue.

Venous malformations

Venous malformations present clinically as soft, compressible, nonpulsatile blue-violaceous papules or nodules that increase in size with measures that increase venous pressure, such as the dependent position. Vessel walls may exhibit calcifications, and phleboliths are considered pathognomonic. Venous malformations are slow-flow lesions that may be present at birth or present later in life as they progress. Magnetic resonance imaging (MRI) for larger lesions is advised to assess the extent of the lesion.

Laser treatment can be indicated for small and discrete venous malformations, such as those on the lip (Fig. 2.7). The goal is to decrease the size of the lesion. Complete clearance may be achieved, but recurrence is not uncommon because venous malformations have a tendency for recanalization. For larger lesions, multiple treatment modalities, including surgery and sclerotherapy, may be used, with the option of a preceding laser treatment for debulking. Laser treatment of venous malformations requires a deeper penetrating laser, and the near-infrared lasers, specifically diode or Nd:YAG, are most commonly implemented. Treatment of these lesions is complex and

best handled by experienced surgeons. Scherer and Waner noted that the benefits of Nd:YAG for complex venous malformations include tissue shrinkage, improved color, and induction of dermal fibrosis, thus reducing the risk of skin loss in surgery and sclerotherapy. In their experience, swelling lasted approximately 2 weeks, and blistering, dyspigmentation, and scarring occurred in less than 5% of patients.

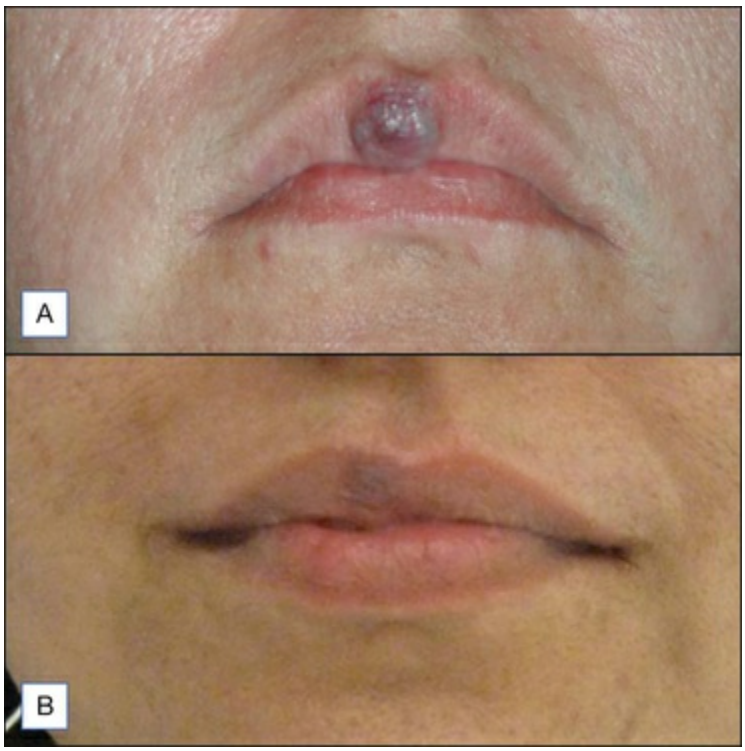


FIGURE 2.7 Venous malformation: (**A**) before and (**B**) after diode laser treatments. There is significant reduction in size and improvement in color. Patient was undergoing further treatments. Courtesy of Dr. R. Rox Anderson.

Venous lakes

Venous lakes are acquired vascular malformations that consist of ectatic venules in the superficial dermis. Venous lakes appear clinically as compressible violaceous papules, most commonly on the lip. Treatment may be initiated for cosmetic purposes or may be prompted by bleeding.

Laser treatment options include PDL for more superficial lesions. For deeper lesions, a deeper penetrating laser, such as diode, alexandrite, or Nd:YAG, is more effective. Using an 800-nm diode, one report used one or two pulses at 9 mm, 30 ms, and 40 J/cm^2, with contact cooling via sapphire chill tip held on the skin for 2 to 3 seconds prior to the laser pulse. The end point is flattening, subtle graying, or deepening of purpura.

Lymphangioma circumscriptum

Lymphangioma circumscriptum is a microcystic lymphatic malformation characterized by clusters of vesicles that may be clear, yellow, or vascular, sometimes with a verrucous texture. A common concern for patients is persistent drainage. CO_2 and Er:YAG lasers can be used in an attempt to scar the superficial component and minimize drainage. There have also been reports of successful treatment with PDL for superficial lesions, although treatments may be limited by depth of penetration and presence of a minimal chromophore target.

Rosacea and telangiectasias

Rosacea commonly presents in association with chronic photodamage with background facial erythema and telangiectasias, defined as superficial vessels 0.1 to 1 mm in diameter. Telangiectasias themselves may also be seen in a wide variety of conditions, including connective tissue diseases, various genodermatoses, and hereditary hemorrhagic telangiectasia. Laser treatment of telangiectasias and facial erythema can improve the appearance in many patients, but again, recurrence is not uncommon. The most commonly used devices include PDL, KTP, and IPL. Near-infrared lasers, specifically diode and Nd:YAG, have been used to treat deeper or larger vessels. Treatment must be tailored to vessel caliber, skin type, and the patient's ability to tolerate purpura. Background erythema may be treated before or after telangiectasias.

Typically three to four monthly nonpurpuric laser treatment sessions with PDL, produce a significant reduction in erythema and telangiectasias (Fig. 2.8). Typical settings include 7- to 12-mm spot, 6- to 10-ms pulse duration, and epidermal cooling. Lower energies are used with larger spot sizes. Lower fluences should be used for patients with intense facial erythema. As always, lower fluences and longer pulse durations are advisable in darker skin types, and parameters vary by device. Residual telangiectasias can then be treated with purpuric (pulse durations of 1.5 to 3 ms) or nonpurpuric settings. Telangiectasia may respond in fewer treatment sessions when purpuric settings are used. The end point for treating vessels is vessel clearance, a transient blue coagulum (Video 2.1), or purpura.



FIGURE 2.8 Rosacea: (**A**) before and (**B**) after four PDL treatments.

Vessels around the nasal ala can be more challenging to treat, and greater efficacy may be achieved with judicious stacking of nonpurpuric PDL pulses. Larger-caliber vessels on the nose may require even longer pulse durations and higher fluences. One study on patients with nasal telangiectasias resistant to PDL and KTP showed successful resolution after PDL alone at 40 ms and 3 mm × 10 mm elliptical spot. Nd:YAG may also be used to treat refractory nasal vessels and facial reticular veins, although the risk of scarring is increased.

Patients should be advised that even when treatment successfully reduces erythema and telangiectasias, follow-up treatments will likely be necessary for maintenance.

Poikiloderma of Civatte

Poikiloderma of Civatte presents in chronically photodamaged areas, most commonly on the neck, chest, and lateral cheeks, with mottled red-brown erythema and associated telangiectasias. IPL may be used for treatment and has the benefits of targeting both pigmentary and vascular components, as well as availability of larger spot sizes to treat larger surface areas. A report of 175 patients treated with IPL showed clearance in more than 80% of patients, with transient side effects in 5%. Scarring or permanent pigmentary change was not observed. PDL has also been implemented to treat the vascular component of poikiloderma of Civatte with good results. Large spot sizes and relatively lower fluences are advised for PDL to limit potential side effects, most commonly a reticulated pattern and hypopigmentation.

Cherry angiomas

Cherry angiomas are the most common vascular growths of the skin and are benign proliferations that tend to be highly responsive to laser treatment, especially PDL. The clinical end point is purpura (Fig. 2.9). Clearance often occurs with one treatment, but larger lesions may require multiple treatments.



FIGURE 2.9 Cherry angiomas: (**A**) before and (**B**) immediately after PDL with expected purpura.

For larger and thicker angiomas, an initial pulse can be delivered while performing diascopy, or compression with a glass slide, to treat the deeper

component. When pulsing through a glass slide there is no cooling of the epidermis. After allowing time for the skin to cool from the initial laser pulse, a second pulse may be placed to treat the more superficial component, if the lesion has not become purpuric. Spider angiomas are treated in a similar manner.

For PDL, suggested settings are 5 to 7 mm, 1.5 to 6 ms, with appropriate epidermal cooling. Settings may need to be adjusted for patients with darker skin types, and as always, parameters vary by device. Reports have also demonstrated success with KTP, IPL, electrodesiccation, and shave excision.

Angiokeratomas

Angiokeratomas are characterized by ectatic superficial dermal vessels and overlying hyperkeratosis. Lesions are often solitary. Less common variants include multiple angiokeratomas, characteristically found on the lower extremities, angiokeratoma of Fordyce in the genital region, angiokeratoma of Mibelli on the dorsal hands and feet, and angiokeratoma circumscriptum. Lesions may also be seen in association with Fabry disease, an X-linked recessive disorder characterized by a deficiency of α-galactosidase A.

Treatment with vascular lasers, such as PDL, may be initiated to treat the vascular component, although a residual keratotic component may persist. Nd:YAG or ablative lasers, such as CO_2 or erbium, may also be implemented. Scarring can occur with aggressive treatment and in sensitive areas, so caution is warranted.

Approach to treatment of vascular lesions

A pretreatment consultation is advisable to include a discussion of the amount of improvement expected, number of treatments, expected treatment effects (such as erythema, purpura, and swelling), potential adverse effects, and aftercare required, including sun protection and avoidance of trauma. Photos before each treatment are recommended.

Eye protection is essential during treatment. If the treatment area is on the face but outside the orbital rim, metal goggles should be placed over the patient's eyes. Stick-on laser shields with appropriate wavelength protection can also be used, but complete adherence to the skin must be visually confirmed. Crying creates moisture which may interfere with the adhesive from the laser shields. For younger children, it is advisable to gently but firmly hold gauze over the stick on laser shields. If the treatment area is within the orbital rim, metal corneal eyeshields must be used. These should be placed carefully to avoid a corneal abrasion.

Many vascular lesion treatments can be performed without anesthesia. Factors to consider include patient age, lesion size, and location. Topical anesthetics (specifically Eutectic Mixture of Local Anesthetics; AstraZeneca) can cause a decrease in vessel size, theoretically diminishing treatment efficacy. Deeper or more extensive lesions may require intralesional lidocaine or nerve

blocks for patient comfort. For local infiltration, lidocaine without epinephrine is generally used to minimize vasoconstriction.

The approach to using general anesthesia in infants and young children varies widely, a consideration that becomes relevant in light of mounting evidence that early treatment of PWSs and hemangiomas may be beneficial, as discussed previously. Treatment without anesthesia in young children may be appropriate for a limited number of pulses. Topical anesthesia can be beneficial but may be limited by maximum weight-based dosing per package insert, and as noted above, some of these medications can cause vasoconstriction. Of note, topical anesthetics are not recommended for ulcerated lesions due to their tendency for higher absorption of the medication.

General anesthesia offers the advantage of avoiding fear and pain in children who will need multiple procedures. It also allows easy placement of the required corneal shield for treatment of eyelid lesions. However, there are risks of general anesthesia. Studies have documented that in healthy patients with vascular lesions the risk is low; however, advantages and disadvantages need to be considered and discussed with the patient and family.

Adverse effects and complications

The risk from laser treatment of vascular lesions primarily consists of scarring and pigmentary changes. Scarring, seen in less than 1% of patients treated with PDL, can be minimized by performing test pulses and assessing appropriate tissue responses before treating the entire lesion. Persistent gray or white discoloration can be signs of epidermal or dermal injury. The risk of permanent hypopigmentation can be minimized by the patient's use of proper sun protection before and after treatment and the physician's attention to tailoring laser parameters for the individual patient. In patients with skin types V and VI, PDL should be used with caution because the depth of the laser may be partially blocked by epidermal melanin, resulting in less effective treatment. It should be noted that darker skin tones generally carry a greater risk of pigmentary change and scarring. Longer wavelength lasers, including the alexandrite and Nd:YAG, also increase the risk of scarring and ulceration, especially given their narrow therapeutic window and potential need for very high energies in treating vascular lesions. These devices should be used with caution and by experienced physicians.

Swelling after PDL treatment is usually mild and transient, resolving within 24 to 72 hours. Effects can be more significant with the nonpurpuric multiple-pass PDL technique and with deeper penetrating lasers. To reduce swelling, patients should apply ice to the area 1 to 2 days post treatment and sleep with the treated area elevated if possible.

The use of lasers has truly revolutionized the treatment of vascular lesions in dermatology. Ongoing device development and improved understanding of vascular lesions will continue to optimize treatment options and outcomes.

Pearl 3

The risk of scarring and pigmentary change is increased in patients with darker skin tones. Risks are also increased when using longer wavelength lasers.

Check online video (Video 2.2).

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3

Laser treatment of pigmented lesions and tattoos

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Summary and Key Features

- The most recent addition to the treatment of pigmented lesions and tattoos is the picosecond (PS) laser available as alexandrite (755 nm), Nd:YAG (532 nm), and Nd:YAG (1064 nm).
- Just as placement of tattoos has gained popularity, so has the number of people interested in their removal.
- Black and blue tattoos are the easiest to fade with the most predictable results, whereas multicolored tattoos are the most difficult.
- Of the various benign pigmented lesions that can be treated with laser, the easiest to treat are lentigines, whereas the most difficult are the nevi of Ota, Ito, and Hori.
- Pigment-specific lasers, such as the PS alexandrite (755 nm), PS Nd:YAG (532 nm), quality-switched (QS) ruby (694 nm), QS alexandrite (755 nm), and QS Nd:YAG (532 and 1064 nm) continue to be the workhorse systems for both tattoo and pigmented lesion removal.
- QS and PS lasers remove tattoo pigment through photoacoustic injury, breaking up the ink particles and making them more available for macrophage phagocytosis and removal.

- Fractional photothermolysis has provided expanded options for pigmented lesion removal in the past decade, although generally more treatment sessions are required and the cost is higher.
- In general, patients with Fitzpatrick skin phototypes I to III have a better response than those with skin phototypes IV to VI because the lasers used for pigment removal can also damage epidermal pigment.
- Topical anesthesia is helpful when treating dermal pigmented lesions and tattoos.
- Factors to consider prior to estimating the number of treatment sessions a patient will need for tattoo removal include: Fitzpatrick skin phototype, location, color, amount of ink used in the tattoo, scarring or tissue change, and ink layering.
- As with any procedure, patient selection and preparation are important to success, and photographs of the lesions should be taken prior to each treatment session.
- Side effects of laser treatment for pigmented lesions include textural change, scarring, pruritus, hypopigmentation or hyperpigmentation, and immediate pigment change.
- Tattoos with white or red ink carry an increased risk of paradoxical darkening after laser treatment, which is why test spots should be carried out prior to the first treatment session.
- Caution should be exercised prior to treatment of a tattoo with an allergic reaction because the dispersed ink particles can elicit a systemic response.
- For pigmented lesions, such as melasma and postinflammatory hyperpigmentation, preoperative and postoperative treatment should include hydroquinone and topical retinoids.
- Postoperative care includes gentle cleansing and a bland emollient while the skin heals.

Introduction

Tattooing has become increasingly popular, with an estimated 7 to 20 million people in the United States with at least one. According to the Pew Research Center, data from 2015 revealed that 14% of all Americans have at least one tattoo and among 25- to 40-year-olds, 40% have at least one tattoo. The data also revealed that 17% regret getting a tattoo. With advances in laser- and light-based technology, as well as their availability, many patients are not only looking to rid themselves of tattoo ink but also seeking removal of benign

pigmented lesions.

In this chapter, we will discuss the use of laser for removing tattoos and ameliorating the appearance of benign pigmented lesions. Although the target for both is pigment, the management of lightening and removal for each condition is distinct.

Pigment removal principles

Quality-switched (QS) lasers have traditionally been the workhorse laser systems for the removal of pigmentation and tattoos; however, the picosecond (PS) laser is the newest addition to the pigmented lesion treatment armamentarium. The laser treatment of pigmented lesions is based on the concept of selective photothermolysis; in essence the chosen laser must emit a wavelength that is specific and well absorbed by the intended target. In the case of tattoos the chromophore is exogenously placed ink found either within macrophages or extracellularly throughout the dermis. In the case of benign pigmented lesions the intended chromophore is melanin found within melanocytes, keratinocytes, or dermal macrophages. Destruction of this pigment is thought to occur mainly through photoacoustic injury. Because the target particles are small, it is important to use pulses of energy that are extremely short to minimize collateral thermal injury to the normal surrounding tissue. For this reason, QS lasers, with energy pulses in the nanosecond range, and PS laser, with energy pulses in picoseconds or trillionths of a second, enable energy to be deposited very quickly. The intense heat transients cause some particles to shatter and kill the cells in which the pigment resides. The rupture of pigment-containing cells eventually triggers phagocytosis and the packaging of pigment fragments for lymphatic drainage and scavenging by dermal macrophages. For epidermal pigment, the pigment-containing cells are killed with the laser pulses, resulting in epidermal necrosis and subsequent sloughing and replacement with normal epidermis.

QS lasers used for pigmented lesions include the QS ruby (694 nm), the QS alexandrite (755 nm), and the QS Nd:YAG (532 and 1064 nm), although it is also possible to use the long-pulsed ruby, alexandrite, and diode lasers, or intense pulsed light (see Chapter 5). Within the past decade, fractional photothermolysis (FP) has gained popularity for its ability to treat pigmented conditions, such as melasma, solar lentigines, nevus of Ota, and postinflammatory hyperpigmentation (PIH) (see Chapter 6).

In 2012 the US Food and Drug Administration (FDA) approved the use of the picosecond alexandrite laser for removal of tattoos. This incredibly fast pulse duration increases photothermal and photomechanical effects, thus resulting in enhanced efficacy for tattoo removal. There is also evidence that fewer treatments are needed to achieve tattoo clearance compared with QS lasers, and lower energies can be used, allowing for less risk of epidermal injury. Since the approval of the PS alexandrite, a PS Nd:YAG (1064 nm and frequency doubled 532 nm) have been made available for commercial use. These new wavelengths now allow for treatment of all tattoo colors. PS lasers are also increasingly being

used for removal of benign pigmented lesions, and in the authors' experience the PS is now the laser of choice for treating solar lentigines, dyschromias, including melasma, and other pigmented lesions. PS lasers have been demonstrated to be safe on skin types III to VI; however, there is a significant risk for hypopigmentation and rebound hyperpigmentation, so caution is advised when treating darker skin types.

In addition, the PS alexandrite has an additional handpiece, the diffractive lens array (DLA), which delivers energy in zones of high fluence surrounded by zones of lower fluence. The areas of high fluence represent approximately 10% of the total treatment area, thus ensuring a significant safety profile. The DLA has been said to simulate nonablative fractional resurfacing and is used for improving dyspigmentation, skin texture, and fine wrinkles. It is FDA approved for the treatment of fine wrinkles and acne scars (Video 3.1).

Lesion selection

Just as important as patient selection is evaluation of the lesion itself. Tattoos can be divided into amateur, professional, cosmetic, medical, and traumatic categories. In amateur tattoos a steel needle is used to deposit ink, which may be at various depths of the skin, whereas in professional tattoos, a hollow needle is used to inject ink into the dermal layer of skin. Amateur tattoos typically contain pigment of unknown sources, such as ash, coal, or India ink (Fig. 3.1). On the other hand, professional tattoo artists often combine ink pigments to achieve novel colors and shading. Cosmetic tattoos using skin-colored tones are important to distinguish, as are medical tattoos, such as those used as radiation markers. For traumatic tattoos it is important to understand the nature of the injury that caused it so as to be aware of the type of material implanted in the skin prior to treatment.



FIGURE 3.1 Amateur tattoo placed on the hand in a person with Fitzpatrick skin phototype IV.

It is critical when treating pigmented lesions other than tattoos that the lesion itself be evaluated for malignancy. Lasers should not be used for any kind of melanoma because even with in situ melanoma recurrence rates are very high. Similarly we recommend against the removal of dysplastic nevi with lasers, even though studies have shown no significant increase in carcinogenic markers after laser stimulation of melanocytes.

General patient selection

At initial consultation for removal of a pigmented lesion, it is important to take a thorough medical history, including a history of allergy to anesthetics (both topical and injectable), current medical conditions, and medications. If a patient is currently taking isotretinoin, laser treatment should be delayed until medication completion because theoretically there is a potential for increased scarring and delayed healing. In addition, it is important to note if the patient was ever treated with systemic gold therapy (e.g., rheumatoid arthritis therapy) because this is an absolute contraindication to PS or QS laser treatment because darkening of gold-containing skin is immediate and irreversible. Prophylaxis is appropriate in patients with a history of herpes simplex virus if treating near the trigger point. A history of keloidal scarring and a tendency toward postinflammatory hypopigmentation or hyperpigmentation should also be documented.

Patient selection for tattoo removal

Although tattoos are increasingly popular, they often become a source of personal regret, because up to 50% of adults older than 40 with tattoos seek their removal. It is critical that a thorough history of the tattoo be taken prior to deciding upon a treatment plan to establish appropriate patient expectations (Box 3.1). Kirby et al. published a scale to help practitioners to estimate the number of treatment sessions needed for tattoo removal to appropriately guide patients who often enter the laser removal process of their tattoos with uncertainty and misconceptions (Table 3.1). In the scale, numerical values are assigned to six parameters: (1) Fitzpatrick skin phototype, (2) location, (3) color, (4) amount of ink used in the tattoo, (5) scarring or tissue change, and (6) ink layering. The points for each parameter are combined, which results in the approximate number of treatment sessions needed to successfully remove the tattoo, plus or minus 2.5.

Box 3.1

Tattoo lesion patient history

- Is it an amateur, professional, traumatic, cosmetic, or medical tattoo?
- How long has it been present?

- What colors of inks/dyes were used?
- Were inks mixed together to make the colors?
- Is there any white or skin-colored ink in the tattoo, to the patient's knowledge?
- Has the patient attempted to remove or alter the tattoo previously? If so, what technique was used?
- Is the patient currently taking a retinoid?
- Is there a history of herpes infection or cold sores in the proposed treatment area?
- Has the patient previously developed keloids or abnormal scars after prior surgery or injury?
- Does the patient currently actively pursue a tan or use a tanning bed or bronzer?
- Any history of gold treatment?
- What is the patient's Fitzpatrick skin type?

Table 3.1

Kirby-Desai scale for estimating number of treatment sessions needed for tattoo removal*

Phototype	Location	Color	Ink amount	Scarring	Layering
I—one point	Head and neck—one point	Black only—one point	Amateur—one point	No scar—zero points	None—zero points
II—two points	Upper trunk—two points	Mostly black with some red—two points	Minimal—two points	Minimal—one point	Layering—two points
III—three points	Lower trunk—three points	Mostly black and red with some other colors—three points	Moderate—three points	Moderate—three points	—
IV—four points	Proximal extremity—four points	Multiple colors—four points	Significant—four points	Significant—five points	—
V—five points	Distal extremity—five points	—	—	—	—
VI—six points	—	—	—	—	—

*Points are listed below each column and assigned depending on six parameters: Fitzpatrick skin phototype, location of the tattoo, color, amount of ink used in the tattoo, scarring and tissue change, and presence or absence of tattoo layering. Physicians should calculate the number using the points listed below each column to arrive at an estimate for number of treatment sessions needed for laser removal (plus or minus 2.5).

In addition to setting a realistic number of treatment sessions for the patient, it is important to alert the patient that some tattoo pigment may still remain and that hypopigmentation may occur in the area, which will leave the outline of

the tattoo sans ink. This is especially true in patients with Fitzpatrick skin phototypes IV to VI or in patients with a tan.

The ideal patient for tattoo removal is an untanned patient with type I or II skin and a dark-blue or black tattoo that has been present for at least a year. The older the tattoo, the better is the response to laser treatment because macrophages are already present in the skin and have been at work trying to actively phagocytose the foreign pigment particles. This natural attempt by the body to remove the foreign tattoo ink pigment is the reason why older tattoos are often illegible and have blurry or indistinct margins. Multicolored tattoos, regardless of background skin color, can be very difficult to remove completely with traditional laser systems and treatment should be performed only after the patient fully understands the potential for incomplete fading, pigmentary alterations, or scarring. Treatment sessions should be spaced at least 6 to 8 weeks apart (Video 3.2).

Patient selection for benign pigmented lesion removal

As with tattoo removal, it is important to assess the patient presenting for benign lesion removal (Box 3.2). The greater the contrast between background skin and pigmented lesion, the more likely the laser surgeon is to achieve success. At preliminary evaluation a Wood lamp examination may be helpful to assess depth of pigment. Understanding whether the lesion is epidermal, present at the dermoepidermal junction, or dermal will guide laser selection and also allow the physician to set realistic expectations for removal.

Box 3.2

Pigmented lesion patient history

- How long has the lesion(s) been present?
- Has a biopsy of the lesion been performed?
- Has it grown, bled without injury, or developed such symptoms as itching or changed color?
- Has the patient attempted to remove or alter the lesion previously? If so, how was this attempted?
- Is the patient currently taking an oral retinoid?
- Is there a personal history of herpes infection or cold sores in the proposed treatment area?
- Has the patient previously developed keloids or abnormal scars after prior surgery or injury?

- Does the patient currently actively pursue a tan or use a tanning bed or bronzer?
- Any history of gold treatment?
- What is the patient's Fitzpatrick skin type?

Patients should not be tanned when treated, and it is important to stress that regular sunscreen use will aid in a durable result (especially in the case of solar lentigines). In patients with darker skin types we recommend pretreating pigmented areas with hydroquinone 4% and ceasing treatment 1 week prior to laser therapy. Post therapy we recommend the use of low-potency topical corticosteroids for 3 to 4 days to prevent any pigment alteration due to inflammation from the treatment itself. Compared with patients with Fitzpatrick skin phototypes I to III, those with skin phototypes IV to VI have a higher risk of pigmentary alteration and scarring.

Lentigines can be treated most reliably, whereas PIH and nevi of Ota and Ito present more of a challenge.

Patient preparation

The area to be treated should always be free of any topicals. Removal of pigmented lesions and tattoos can be quite painful for the patient, especially if a large area is to be treated. On the face, we recommend topical anesthetic mixtures that can be compounded at the pharmacy, consisting of betacaine, lidocaine, and tetracaine (a typical concentration is 7% of each), or the patient can use a commercial preparation, such as LMX-4 or EMLA. A thick layer of this mixture is spread evenly over the treatment area, with anesthesia taking place usually within 45 minutes. Penetration of the topical anesthetic can be enhanced by putting the medication under occlusion or applying warm towels over the area. Caution should be exercised if the area is large, because topical anesthetics can produce toxicity. Anesthetic should always be completely removed prior to treatment.

Ice is another option, although we recommend ice cubes wrapped in frozen gauze rather than ice packs as the latter tend to not maintain an even temperature. The ice should precede the laser treatment with caution to ensure that no water is left behind. For dermal pigmented lesions on the face, such as nevus of Ota, we sometimes will anesthetize the area with 1% lidocaine.

After informed consent is obtained, pretreatment photographs are taken. As with any medical procedure, universal precautions should be followed. Many QS and PS lasers use a cone or cylinder placed between the handpiece and the skin to catch any skin debris ejected during laser treatment. Because the cones contain fragments of skin, it is important to use gloves when removing them from the laser after treatment.

Eye safety is also paramount when using lasers. Wavelength-specific protective glasses or goggles must be worn by the patient, provider, and staff at

all times during a laser procedure. If the area to be treated is on the eyelid or near the orbit, internal metal eye shields should be placed for the patient.

Pearl 1

Most QS lasers come with a plastic spacer or cone that is attached to the handpiece and touches the skin surface. As a result the inside of the barrel becomes contaminated with skin debris ejected from the patient's skin surface. Depending on the device, after treatment, the practitioner has several options. The cone can be either cleaned and sterilized, discarded, or given to the patient to bring to their next treatment. In our experience, patients often forget to bring the cone back, so we prefer to clean and sterilize the cone after each use.

Pearl 2

Because many laser goggles look alike, it is important to read the label on the glasses each time before putting them on or giving them to a patient to make sure they block the particular wavelength being used. Always ensure that the lenses provide an optical density (OD) of at least 6. If the patient goggles obstruct the treatment area in the periorbital area, an anodized external metal eye cup can be used to protect the patient's eyes.

Pearl 3

QS and PS laser light can cause inadvertent permanent retinal damage and vision loss if the eyes are not appropriately protected. For this reason, when treating nevus of Ota on the eyelids or cosmetic eyeliner tattoos, it is paramount that metal corneal shields be placed under the eyelids to protect the globe prior to attempts to treat the eyelids. Two drops of ophthalmic tetracaine are instilled onto the conjunctiva. Next, a thin coat of ophthalmic erythromycin ointment is applied to the concave surface of the eye shield, the lower lid is retracted, the patient is asked to look up, and the lower edge of the shield is inserted interior to the lower eyelid. Next, the patient is asked to look down, and the upper edge of the shield is inserted interior to the upper lid.

Treatment techniques

In general

Prior to commencing full treatment in darkly pigmented individuals, it is advisable to perform test spots on pigmented lesions or tattoos. Test spots should be evaluated at 4 to 6 weeks for hypopigmentation or hyperpigmentation and efficacy. When using a QS or PS laser, the initial desired response for epidermal and dermoepidermal pigmented lesions is immediate lesion whitening or graying, which represents cavitation. This may be more difficult to gauge if using an Intense Pulsed Light (IPL) system in which the primary end point in pigmented lesions is subtle darkening (see

Chapter 5). Within 20 to 30 minutes, this gray converts to erythema. In dermal lesions the immediate whitening is less vivid.

A snapping sound is common with QS or PS laser use because pigment particles and the cells that contain melanin or tattoo particles are heated and explode. The lesion is fully covered with laser pulses. The immediate whitening keeps additional light from entering the skin due to reflection. Pulse stacking should be avoided because this may increase the risk of scarring and unnecessary thermal injury. If significant energy is absorbed by a pigmented lesion, pinpoint bleeding may occur, as occasionally occurs with tattoos. Performing two to four treatments of a tattoo all in one day (waiting for the immediate whitening to fade between treatments) seems to increase the degree of fading achieved in one visit; however, the popularity of this is unclear because it requires the patient to spend a significant amount of time in the office. Kossida et al. initially described sequential treatments in one day as the "R20" method because it takes approximately 20 minutes for the laser-induced gas bubbles, visualized as the overlying whitening, to dissolve. Subsequent to this, topical perfluorodecalin (PFD) was shown to immediately dissolve these gas bubbles, eliminating the 20-minute waiting period for treatments. PFD is now commercially available for in-office use (DeScribe Transparent Patch, ONLight Sciences/Merz, Raleigh, NC). In addition, the use of PS lasers has been shown to decrease the total number of treatments needed for tattoo clearance compared with QS lasers.

Pearl 4

After tattoo treatment, the lesion often turns a gray-white. When treating a multicolored tattoo with more than one laser wavelength, the additional treatment pass should be carried out only after the whitening has fully dissipated, which may take 10 to 20 minutes.

Case Study 1

Uneven Tissue Response in a Black Tattoo

AR is a 39-year-old man with an amateur tattoo on the hand. The tattoo appears black, and the patient reports that his "friend put it there." The patient does not have a tan. After icing the area for 15 minutes, the tattoo is treated with the QS Nd:YAG laser at a fluence of 3.0 J/cm^2. The tattoo responds immediately and turns white and then erythematous. Unlike the rest of the tattoo, the central portion develops an erosion immediately upon treatment. This occurred because, in amateur tattoos, pigment is not placed at a uniform depth or in a uniform concentration. The tattoo was treated from the periphery to the center. Although the periphery responded well, it was too much energy for the center, which led to immediate epidermal sloughing and pinpoint bleeding (see Figs. 3.1 and 3.2).



FIGURE 3.2 Amateur tattoo immediately after treatment with the QS Nd:YAG laser showing punctuate bleeding.

Patients and equipment for dark blue or black tattoo treatment

Fitzpatrick skin phototypes I to III

In lighter-skinned patients (in the absence of a tan or bronzer), the practitioner has several options (Table 3.2). The QS and PS alexandrite (755 nm), the QS ruby (694 nm), and the QS and PS Nd:YAG (1064 nm) lasers are all effective for dark blue and black tattoos (Figs. 3.3 and 3.4). In the case of traumatic tattoos that appear black, it is important to know the origin of the trauma because such tattoos may react with a small explosion (e.g., gun powder tattoo) after laser treatment.

Table 3.2

Laser choices based on tattoo ink color

A				
QS laser	**Black**	**Blue**	**Green**	**Red**
Alexandrite 755 nm	X	X	X	
Ruby 694 nm	X	X	X	
Nd:YAG 1064 nm	X	X	X	
Nd:YAG 532 nm				X
Nd:YAG 650 nm			X	
B				
PS laser	**Black**	**Blue**	**Green**	**Red**
Alexandrite 755 nm	X	X	X	
Nd:YAG 1064 nm	X	X	X	
Nd:YAG 532 nm				X



FIGURE 3.3 Black amateur tattoo on the arm seen (**A**) preoperatively and (**B**) 6 weeks later following a single treatment with the QS ruby laser, with only small speckles of ink remaining.



FIGURE 3.4 (**A**) Professional tattoo on ventral wrist and (**B**) tattoo after eight 755-nm PS laser tattoos demonstrates significant fading of pigment but moderate hypopigmentation.

Fitzpatrick skin phototypes IV to VI

In darker-skinned patients, lasers having longer wavelengths are generally safer because they spare the epidermis to a greater degree than shorter-wavelength lasers. Thus the QS and PS Nd:YAG (1064 nm) is the laser of choice.

Patients and equipment for red tattoo treatment

The optimal laser wavelength for removing red tattoo ink is the PS or QS 532 nm (frequency-doubled Nd:YAG). This wavelength can cause both hyperpigmentation and hypopigmentation in darker-skinned patients, so treatment should be limited to phototype I to III patients. It should be noted that red tattoo ink is often the culprit for allergic reactions after tattoo placement and granulomatous reactions in the tattoo itself (Fig. 3.5). Laser removal of the red ink can cause greater dispersion of the antigen, resulting in urticaria or a systemic allergic reaction. In these cases an ablative CO_2 or Er:YAG laser can be used to vaporize the tattoo (Fig. 3.6). If a QS or PS laser is used, the patient should be covered with systemic corticosteroids and antihistamines, and the laser surgeon should proceed with caution (see Case Study 2).

Case Study 2

When Laser Removal is Not an Option

TV is a 53-year-old woman who decided to have a red daisy on a green stem placed on her ankle 1 year ago. Approximately 3 months after getting the tattoo, she complained of itching in the area and noticed a gradual thickening of the skin. She had not experienced this with her other tattoos and has one on the dorsal foot of the same lower extremity that was normal in appearance. She tried clobetasol cream to the area, which initially helped and then failed, and then she used flurandrenolide (Cordran) tape, which worked to alleviate the itch but not the size of the reaction in the area. On exam, the patient is skin phototype V with a thick plaque on the ankle, in which one can begin to make out individual flower petals. No visible red ink remained but the green stem was still present. Given her background skin tone and history of red ink, the decision was made to forgo laser therapy of the area in favor of surgical excision. The pathology showed a pseudolymphoma resulting from a granulomatous reaction to the red ink. In this case, QS or PS laser therapy would have been of minimal benefit and surgical therapy became the mainstay of treatment (Fig. 3.7).



FIGURE 3.5 Multicolored tattoo showed allergy to yellow ink. The area was successfully treated with class I topical corticosteroids, thus avoiding the need to remove the tattoos with laser.

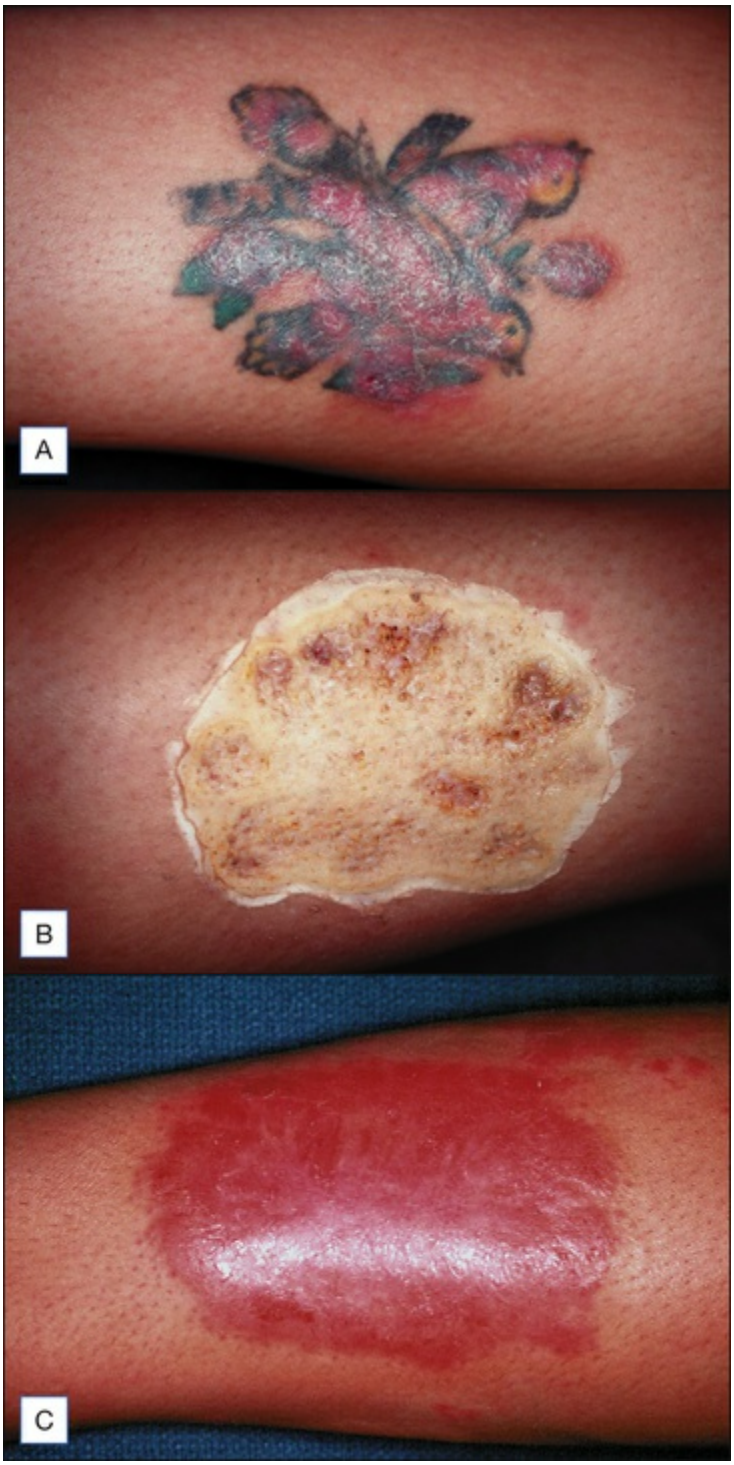


FIGURE 3.6 Tattoo granulomas from an allergic reaction to the *red* (cinnabar or mercury tattoo ink) color in a multicolored tattoo seen (**A**) preoperatively, (**B**) immediately after removal of the tattoo and all granulomas with the vaporizational mode of the CO_2 laser, and (**C**) 3 months later showing the residual erythematous permanent scar.



FIGURE 3.7 Biopsy-proven pseudolymphoma in the portions of the tattoo decorated with *red* ink.

Patients and equipment for green tattoo treatment

The optimal laser wavelength for removing green tattoo ink is the QS ruby laser (694 nm). Because this wavelength is well absorbed by melanin, caution should be used because injury to melanocytes can lead to transient hypopigmentation and even permanent depigmentation, as well as textural change. In addition, PS and QS alexandrite are also excellent at fading green ink. The goal of treatment should be immediate tissue whitening with minimal or no bleeding.

Patients and equipment for epidermal lesions

Solar lentigines, lentigo simplex, and ephelides

Pigment that is in the epidermis accounts for such lesions as solar lentigines, lentigo simplex, and ephelides. Any laser system that damages the epidermis will therefore result in improvement in one to two treatment sessions (Figs. 3.8 and 3.9). Conversely, if the epidermal damage is part of a deeper destruction, there may be scarring or dyspigmentation afterward. FP can be considered for these conditions, especially if the lesions are widespread (see Chapter 6), but the mainstay lasers are the QS or PS alexandrite, QS or PS Nd:YAG (532 nm), and QS ruby lasers. Long-pulsed lasers and IPL can also be effective (see Chapter 5).

Pearl 5

After treatment of solar lentigines or ephelides, it is important for the patient to practice regular, diligent sun protection to prevent recurrence of pigment. Mineral sunscreens are preferable because they provide a physical block to ultraviolet (UV) rays. Even if the patient reports minimal outdoor exposure, the

physician should remind the patient that even driving can cause repigmentation because windshield glass does not filter UVA light.



FIGURE 3.8 Multiple small brown lentigines on the back of the hand seen (**A**) preoperatively and (**B**) with nearly complete resolution 6 weeks after a single treatment with the frequency-doubled QS Nd:YAG laser.

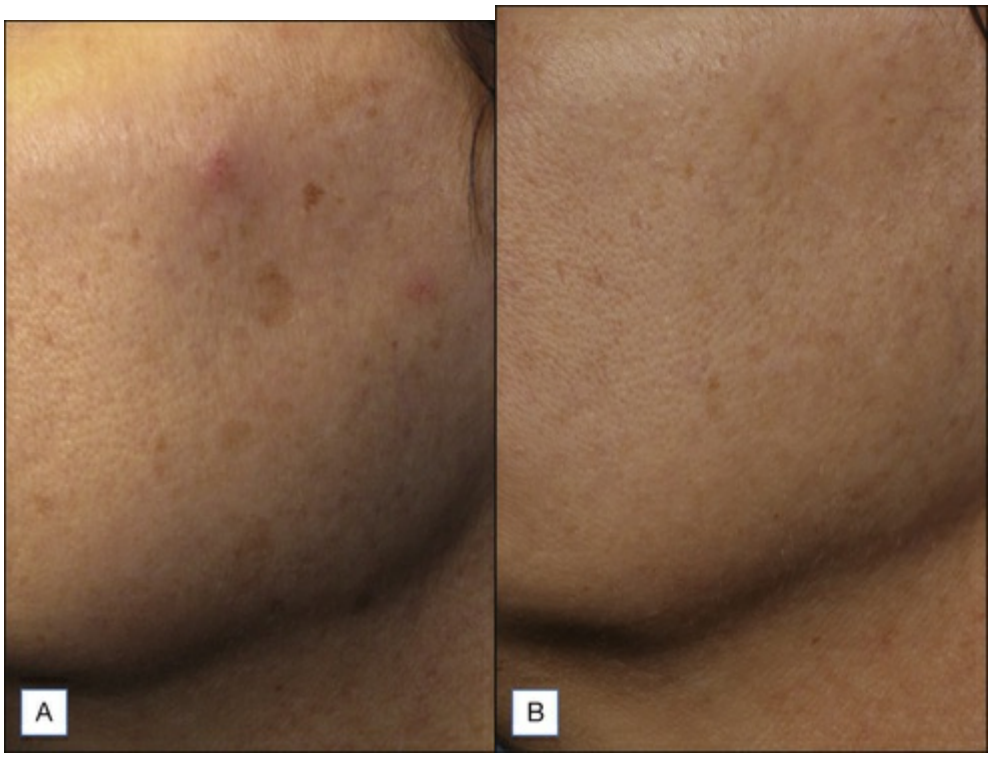


FIGURE 3.9 Lentigines at baseline (**A**) and (**B**) 1 month after one 755-nm PS laser.

Labial melanotic macules

Melanotic macules on the lip vermilion are a feature of several entities, including physiologic racial pigmentation, Laugier-Hunziker syndrome, and Peutz-Jeghers syndrome. These can be treated using the QS ruby or QS or PS alexandrite or frequency-doubled QS or PS Nd:YAG lasers. In the case of the syndromes, patients should be made aware that new macules will develop over time (Fig. 3.10).

Pearl 6

A mental nerve block using 0.3 to 0.5 mL of lidocaine provides adequate anesthesia for treatment of labial melanotic macules on the lower lip, whereas an infraorbital nerve block provides anesthesia for the upper lip. Both can be achieved quickly via an intraoral approach. For the upper lip, inject between the first and second premolars, angling the needle upwards towards the midpupillary line. For the lower lip, inject between the first and second lower premolars.



FIGURE 3.10 Multiple small lentigines of the mucosal lip vermilion seen with Peutz-Jeghers syndrome seen (**A**) preoperatively and (**B**) 6 weeks after three treatments with the QS ruby laser, showing excellent fading without scarring.

Café au lait macules and nevus spilus

Café au lait macules (CALMs) vary in color, size, and shape, but histologically the excess pigment is found at the basal layer. When darker macules exist with the CALM, it is referred to as a nevus spilus. Before treating CALMs, one should always take a careful history to rule out neurofibromatosis (if multiple macules exist). Lasers that are usually used to treat these lesions include the QS Nd:YAG, QS ruby, and QS alexandrite lasers, and currently the PS laser can be used. Patients with darker skin are at risk for hyperpigmentation and hypopigmentation. Light-skinned patients are the ideal candidates for CALM removal, but recurrences, residual hyperpigmentation, and incomplete pigment removal are common. Treatment sessions are spaced at least 8 weeks apart, and clearance requires at least two to four treatment sessions (Fig. 3.11).



FIGURE 3.11 Solitary CALM on the leg showing the complication of hyperpigmentation of the lateral portion of the lesion 12 weeks after testing with the QS Nd:YAG laser.

Patients and equipment for dermoepidermal lesions

Lesions in this category include Becker nevus, melasma, PIH, drug-induced hyperpigmentation, and nevocellular nevi. Pigment is present at the dermoepidermal junction, and in the case of a Becker nevus, in addition to the pigment, there are often terminal hairs in the lesion itself. Nevocellular, junctional, and compound melanocytic nevi should be treated with laser only if the operator is certain that they are benign.

Becker nevus

The hyperpigmented areas of a Becker nevus have shown improvement when treated with the PS alexandrite, QS ruby, QS Nd:YAG, and 1550-nm fractional erbium-doped fiber laser. Of the QS lasers, the ruby is slightly more effective than the Nd:YAG. Treatment sessions should be spaced 8 to 12 weeks apart, and three to five treatment sessions are usually necessary. With any of these methods, fading is generally incomplete and patchy. The terminal hairs can be removed with hair removal lasers (see Chapter 4).

Melasma

Melasma is caused by a number of factors, including hormonal changes, sun exposure, and medication use. It typically presents as patchy hyperpigmented areas on the face in women. Unfortunately, although lasers can improve the

appearance of melasma, this is usually short-lived as recurrences are common. Patients must be counseled on the proper use of broad-spectrum sunscreen at all times and be aware that treatment of melasma may result in PIH. The QS ruby, QS alexandrite, QS Nd:YAG, Er:YAG, 1550-nm fractionated erbium-doped fiber laser, and fractional CO_2 laser have all been reported as treatment modalities to improve melasma, although there is no definitive cure. Kauvar has reported success using QS Nd:YAG at low fluences. Worsening of the melasma and recurrence after "successful" treatment are frequently seen. Treatment sessions are usually spaced 4 to 8 weeks apart, and four to eight sessions are needed. It is important to not attempt correction of melasma during spring or summer because incidental sunlight exposure will likely counteract any improvement made by the laser itself. As with PIH, pretreatment with topical hydroquinone or with Kligman's formula (5% hydroquinone, 0.1% tretinoin, 0.1% dexamethasone) is likely to enhance results, and these topicals should be continued as part of a maintenance regimen.

The authors of this chapter are currently investigating the use of the PS alexandrite for the treatment of melasma, using both the flat optic and DLA handpiece. Spot size and energies for the flat optic range from 0.9 to 4.8 mm and 0.91 to 2.65 J/cm^2; 2 to 5 Hz, one to two passes; for the DLA a 6-mm spot size, 0.57 J/cm^2, 5 to 10 Hz, two to six passes were used (Figs. 3.12 and 3.13).



FIGURE 3.12 Melasma at baseline (**A**) and (**B**) after four treatments with the 755-nm PS laser.



FIGURE 3.13 Melasma at baseline (**A**) and (**B**) after five treatments with the 755-nm PS laser.

Postinflammatory hyperpigmentation

PIH occurs due to hemosiderin and/or melanin deposition. Because this condition arises due to inflammation, it is important to use low fluences and ensure that the patient does not develop significant posttreatment erythema to provoke additional PIH. For this reason, test spots are encouraged prior to treating large areas. The laser system currently used most often for PIH is the FP system, even though treatment with this laser has been reported to induce PIH itself (see Chapter 6). PIH can occur on the face but can also be a result of hemosiderin deposition after sclerotherapy. For postsclerotherapy hyperpigmentation, the QS ruby or IPL (see Chapter 5) can be used (Fig. 3.14). All patients being treated for PIH on the face should use topical hydroquinone 4% cream, along with a broad-spectrum sunscreen before and after treatment. Before using a laser for facial PIH, we recommend a trial of topical retinoids and a series of chemical peels to try to improve the discoloration with laser as the final step. Recurrence is frequently seen, especially after sun exposure.

Pearl 7

Controversy exists regarding the long-term use of hydroquinone. Although it is reasonable to offer patients peels, there are over-the-counter preparations that are hydroquinone-free if the patient wishes to maintain their post-laser results. Ingredients in these hydroquinone-free products include such compounds as kojic acid, anisic acid, and arbutin.



FIGURE 3.14 Area of postinflammatory hyperpigmentation following sclerotherapy for small leg veins seen (**A**) preoperatively and (**B**) 6 weeks after multiple treatments with the QS ruby laser.

Drug-induced hyperpigmentation

Minocycline, doxycycline, amiodarone, and azidothymidine (AZT, zidovudine) can cause hyperpigmentation of the skin that appears as gray-brown to brown. Type II minocycline hyperpigmentation has been reported to clear after use of the QS alexandrite laser and the QS Nd:YAG laser. Goldman et al. have reported use of the PS alexandrite for the treatment of minocycline-induced postsclerotherapy hyperpigmentation. Discontinuation of the medication is important, and treatments should be started after a trial of hydroquinone 4%.

Congenital nevi

Congenital nevi that are too large for surgical removal may be considered for treatment with laser. Unfortunately, scarring is common, especially on the anterior torso, flanks, or arms. Authors have reported success with the QS lasers in the past and more recently the PS alexandrite, Er:YAG and the CO_2, or a combination of the QS lasers with ablative resurfacing. It is important to note that most studies have evaluated children with congenital nevi rather than adults who desire removal, and, in general, the value of removing congenital nevi with any laser has not been substantiated because residual pigment and

repigmentation are common.

Patients and equipment for dermal lesions

Dermal lesions have pigment deeper in the dermis that require devices with longer wavelengths. Examples of such lesions include nevi of Ota, Ito, and Hori, and congenital dermal melanocytosis also known as Mongolian spots. Argyria is an additional example of a dermal process that manifests as a result of ingestion of silver and can be treated with QS laser.

Nevi of Ota, Ito, and Hori

Nevus of Ota presents on the face as a blue-black, brown, or gray patch that develops after birth or in adolescence with a unilateral distribution that may involve the sclera. Nevus of Ito is similar, but its location is usually on the shoulder. Hori nevus is typically bilateral and located in the malar region. In darker-skinned (types IV to VI) patients the QS Nd:YAG laser at 1064 nm is usually the safest laser to lighten a nevus of Ota, Ito, or Hori. In lighter-skinned patients, QS ruby laser at 694 nm and QS alexandrite laser at 755 nm can also be used. A fractionated 1440-nm Nd:YAG laser has been reported to clear nevus of Ota. Most recently a PS alexandrite has been used for treatment of nevus of Ota. Treatments are usually spaced 3 to 4 months apart, with up to 10 treatment sessions needed for clearance with QS lasers and two to three treatment sessions with the fractionated laser. Patients should be informed that the pigment on the cheek and temple responds better to laser treatment compared with that on the upper and lower eyelid. Nevus of Ota patients should be made aware that the sclera component of the lesion is not amenable to treatment with current technology.

Congenital dermal melanocytosis

Mongolian spots typically appear as blue-gray macules of varying size on the body that resolve in childhood but occasionally persist into adulthood. These can be treated with the PS alexandrite, QS alexandrite, ruby or Nd:YAG laser, although PIH is a risk. Sacral spots tend to be more laser-resistant than extrasacral Mongolian spots, and treatment in childhood portends better results.

Argyria

Argyria is a rare skin disease caused by ingestion of silver salt or silver particles used in traditional remedies. The pigment granules that result in the blue-gray discoloration associated with argyria are usually found in the upper dermis. Treatment of argyria can be successfully accomplished using the QS 1064-nm Nd:YAG at low fluences. Special attention should be given to anesthesia in this situation because treatment is very painful.

Amalgam tattoos

Amalgam tattoos on the gingival or buccal mucosa result from placement of silver fillings in the teeth and can be of cosmetic concern, especially if on the anterior gingival surface. These metallic deposits can be removed using the QS ruby or QS alexandrite laser.

Pearl 8

To anesthetize the gingiva, consider tetracaine gel. Application is performed with a cotton-tip applicator, and onset of action is usually less than 1 minute. However, it is important that the gel be removed with gauze prior to laser treatment.

Postoperative care

If a Q-switched laser was used for treatment of dermal lesions, the area will appear somewhat abraded after treatment. Apply a layer of petrolatum beneath a dressing of nonstick gauze and paper tape. Instruct the patient to change the dressing daily after first gently cleansing the area with soap and water. This should be continued until the area has completely reepithelialized. A dry crust should never be allowed to form. The treatment area should heal within 5 to 14 days. No specific wound care is needed after the treatment of epidermal lesions. A very subtle eschar appearing as a darker version of the original lesion will form and peel off within 7 to 10 days.

If an IPL system was used for treatment, typically only erythema is seen postoperatively and dressings are not generally required (see Chapter 5). After FP, broad-spectrum sunscreen and noncomedogenic moisturizer should be applied for at least 1 week (see Chapter 6).

Troubleshooting for tattoo removal

When evaluating a tattoo patient prior to initiating therapy, carefully palpate and examine the site to be sure that no preexisting scarring, hypopigmentation, or induration is present. Many patients may not realize that the actual tattooing procedure can cause both scars and loss of normal pigmentation.

Incomplete removal of the tattoo is a common problem following laser treatment and should be thoroughly discussed with patients. If treatment is ineffective, an increase in energy fluence may be necessary, but care must always be taken to stay within safe treatment parameters to avoid scarring or pigmentary alterations. In some cases, changing to a different laser may be worthwhile due to the intrinsic differences in wavelengths, pulse durations, and spot sizes. It is also important to stress that the treated skin may remain hypopigmented and may never completely blend with surrounding skin.

Troubleshooting for pigmented lesion removal

As with tattoos, incomplete removal of benign pigmented lesions following

laser treatment is the chief problem. However, unlike tattoos, only a few additional treatments will usually lead to total or near-total removal of CALMs, lentigines, and nevi of Ota and Ito. Increasing the energy fluence often produces improvement in resistant lesions. When treating lentigines, if the patient has lesions on both his or her hands and face, it is always best to treat the hand lesions first so that if an untoward reaction results it will result in less patient unhappiness than if the same problem had developed on the face. This is especially true in patients with darker skin types. However, the face heals much faster and tends to be more forgiving than the hands.

Side effects and complications

Alterations in pigmentation

Despite appropriate precautions, pigmentary alteration can still occur following laser treatment of tattoos or benign pigmented lesions. The hyperpigmentation usually improves with time or use of topical bleaching creams, such as 4% to 5% hydroquinone compounded with 1% to 2% hydrocortisone and 0.0% to 0.1% tretinoin. Hypopigmentation is more difficult to treat, but the use of the excimer laser or narrow-band ultraviolet (UVB) light may help. Still, multiple treatments are often required, and incomplete resolution is common. Whereas many cases of pigmentary alteration will resolve spontaneously over time, some cases may be permanent.

If a patient who has taken gold therapy is inadvertently treated with a QS or PS laser, immediate darkening of the gold particles in the skin may result. This is thought to occur due to alteration in the gold particles present in the skin. A long-pulsed ruby laser has been reported to clear the resultant discoloration.

In skin phototypes IV to VI, decorative tattoo removal can be especially challenging because the current devices used to treat tattoos are also used to treat benign pigmented lesions. As a consequence, such complications as epidermal blistering, hypopigmentation, and incomplete tattoo removal can be anticipated and should be evaluated through test spots prior to the first treatment session. Waiting 6 to 8 weeks prior to full treatment will allow such pigmentary complications to reveal themselves so the laser surgeon can plan appropriately.

Pearl 9

If a test spot darkens on a cosmetic facial tattoo, rather than try to treat the dark spot, consider surgical excision of the test spot and proceeding with ablative and/or fractional resurfacing.

Paradoxical darkening of tattoo pigment

Cosmetic tattooing is the process of using tattoo ink to enhance the shape of the lips, to augment the appearance of the eyebrow, to accentuate eyelids, or to reconstruct the appearance of the areola following mastectomy. When a patient desires subsequent removal of this type of tattoo, extreme caution should be

exercised because in most of these situations white ink pigment has been used to achieve the skin-colored tattoo tone. In noncosmetic tattoos the presence of pastel colors, such as light blue, turquoise, yellow, light green, lavender, and pink, should also raise suspicion of white ink additives. Treatment may result in immediate and permanent tattoo darkening in white and even in red tattoos. The laser pulse can reduce ink from rust-colored ferric oxide (Fe_2O_3) to jet-black ferrous oxide (FeO). Similarly, white ink made up of titanium dioxide (TiO_2, Ti^{4+}) can be reduced to blue Ti^{3+} upon laser treatment. Such posttreatment darkening appears immediately. For this reason, a single, small inconspicuous test spot is recommended to ensure that this complication does not occur. Even after testing, it is appropriate to obtain the patient's written consent that he or she understands tattoo ink darkening may still occur during future treatments and that it may be permanent. The darkening usually becomes apparent after the immediate whitening has faded. If pigment darkening does occur in a decorative tattoo, it may be improved with subsequent treatment with the QS Nd:YAG laser operated at 1064 nm. Geronemus et al. published a small case series successfully treating patients with paradoxical tattoo darkening with the PS Nd:YAG frequency-doubled laser.

Thermal injury and scarring

Textural changes can be minimized through the use of a large spot size and appropriate spacing of treatments at 6 to 8 weeks. Significant thermal injury and subsequent scarring are rare (approximately 5%) when treating dermal pigmented lesions if the proper laser guidelines are followed and the appropriate treatment parameters are used. When they do occur, they are most likely to happen on the chest, outer upper arm, and ankle. Ideal wound care with normal saline cleansing and application of petrolatum with a nonstick gauze dressing may prevent infection and help to minimize scarring. In spite of these efforts, if scarring does occur, subsequent treatment with a series of pulsed dye laser treatments, a series of injections of low-dose triamcinolone acetonide directly into the scar, or topical application of silicone gel sheeting along with scar massage over a period of several weeks may help to improve the appearance of the scar. Cobblestone texture seen within 2 weeks of treatment is a sign of incipient scarring and may be reversed with twice-daily application of class I topical corticosteroids. Scarring after QS laser treatment of epidermal lesions is extremely rare.

Special situations

Tattoo granulomas

Allergic granulomas to tattoo ink are probably most commonly seen to the cinnabar in red-colored inks. In these situations the use of any of the QS lasers is not recommended because it may worsen the allergic reaction and produce systemic symptoms or even anaphylactic reactions. The use of an ablative laser, such as the carbon dioxide or Er:YAG laser, can be used to remove the

offending ink and also destroy the granulomas at the same time. Biopsies should be considered before laser treatment to rule out sarcoidosis, infectious granulomas (such as atypical mycobacterial infections), and other entities.

Multicolored tattoos

When treating a tattoo of multiple colors, especially black, red, or green, more than one laser may be required to maximize the degree of improvement. In these situations the black outline of the tattoo is usually first treated with infrared light from the QS Nd:YAG laser operated at 1064 nm. After that portion of the treatment has been completed, the green light from the frequency-doubled QS Nd:YAG laser operated at 532 nm is used to treat the red portions of the tattoo. If green tattoo ink is also present, red light from the Q-switched ruby or alexandrite lasers is used. Alternatively, the QS Nd:YAG with a 650-nm wavelength dye-containing handpiece can be used. Care should be taken to avoid overlapping the treatment pulses as much as possible by matching the size of the laser beam to the amount of the tattoo color being treated. By using this technique, it is often possible to treat the entire tattoo at one time, resulting in more rapid resolution of the different colors than if they were treated individually at different visits. Other colors respond unpredictably to specific wavelengths, with the treatment performed mostly by trial and error. If prominent immediate whitening in the tattoo ink is noted, that laser wavelength will tend to achieve fading of that color (Table 3.3).

Table 3.3

Tattoo pigments used to create specific tattoo colors

Tattoo color	Source
Black	Carbon, iron oxide, India ink, lead, gunpowder
Red	Cinnabar (mercuric sulfide), cadmium selenide, sienna, azo dyes
Green	Chromium oxide, malachite green, hydrated chromium sesquioxide, lead chromate
Blue	Cobalt aluminum
Brown	Ochre
Yellow	Cadmium sulfide, ochre, curcumin yellow
Violet	Manganese violet
White	Titanium dioxide, zinc oxide

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4

Laser hair removal

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Summary and Key Features

- Laser hair removal (LHR) is the most commonly requested cosmetic procedure in the world.
- The extended theory of selective photothermolysis enables the laser surgeon to target and destroy hair follicles, thereby leading to both permanent and temporary hair removal.
- The ideal candidate for LHR is fair skinned with dark terminal hair; however, LHR can currently be successfully performed in all skin types.
- Thin hairs and hairs with white, blond, and red color are extremely difficult to treat with LHR devices.
- Wax epilation should be avoided prior to LHR treatments.
- Lasers pose a safety risk to both the patient and device operator.
- Informed consent should be reviewed with every patient prior to treatment.
- Wavelength, spot size, pulse duration, and skin cooling are key variables that can be used to tailor laser–tissue interactions for a given patient.
- Approximately 15% to 30% of hairs can be removed with each treatment session using ideal parameters. Remaining hairs are often thinner and lighter in color.
- The most common complication is pigmentary alteration, which can be temporary or permanent.

Introduction

The nonspecific damage of human hair follicles with a laser was noted more than 50 years ago. However, it was not until the theory of selective photothermolysis was proposed by two Harvard dermatologists, Rox Anderson and John Parrish, that the concept of selectively targeting a particular chromophore based on its absorption spectrum and size was realized. In 1996 this group also reported the first successful use of a normal-mode ruby laser for long-term and permanent hair removal.

Removing unwanted body hair is currently a worldwide trend, and hair removal using laser or other light-based technology is one of the most highly requested cosmetic procedures. Prior to the advent of laser hair removal (LHR), only temporary methods for removing unwanted hair were available, such as bleaching, plucking, shaving, waxing, and chemical depilatories. Threading, a form of epilation using a cotton thread, is a common practice in some cultures. In addition to not providing permanent hair removal, these methods are also inconvenient and tedious. Electrolysis is a technique in which a fine needle is inserted deep into the hair follicle and uses electrical current, thereby destroying the hair follicle and allowing for permanent hair removal of all types of hair. However, this technique is impractical for treating large areas, extremely tedious, operator-dependent, and with variable efficacy in achieving permanent hair removal. Eflornithine (α-difluoromethylornithine [DFMO]) is a topical inhibitor of ornithine decarboxylase that slows the rate of hair growth and is currently US Food and Drug Administration (FDA) cleared for the removal of unwanted facial hair in women. In this chapter we provide a detailed overview on LHR, including discussion of hair follicle biology, the science behind LHR, key factors in optimizing treatment, and future trends.

Basic hair biology

The hair follicle is a hormonally active structure (Fig. 4.1) that is anatomically divided into an infundibulum (hair follicle orifice to insertion of the sebaceous gland), isthmus (insertion of the sebaceous gland to the insertion of the arrector [erector] pili muscle), and inferior (insertion of the arrector pili to the base of the hair follicle) segments. The dermal papilla provides neurovascular support to the base of the follicle and helps to form the hair shaft.

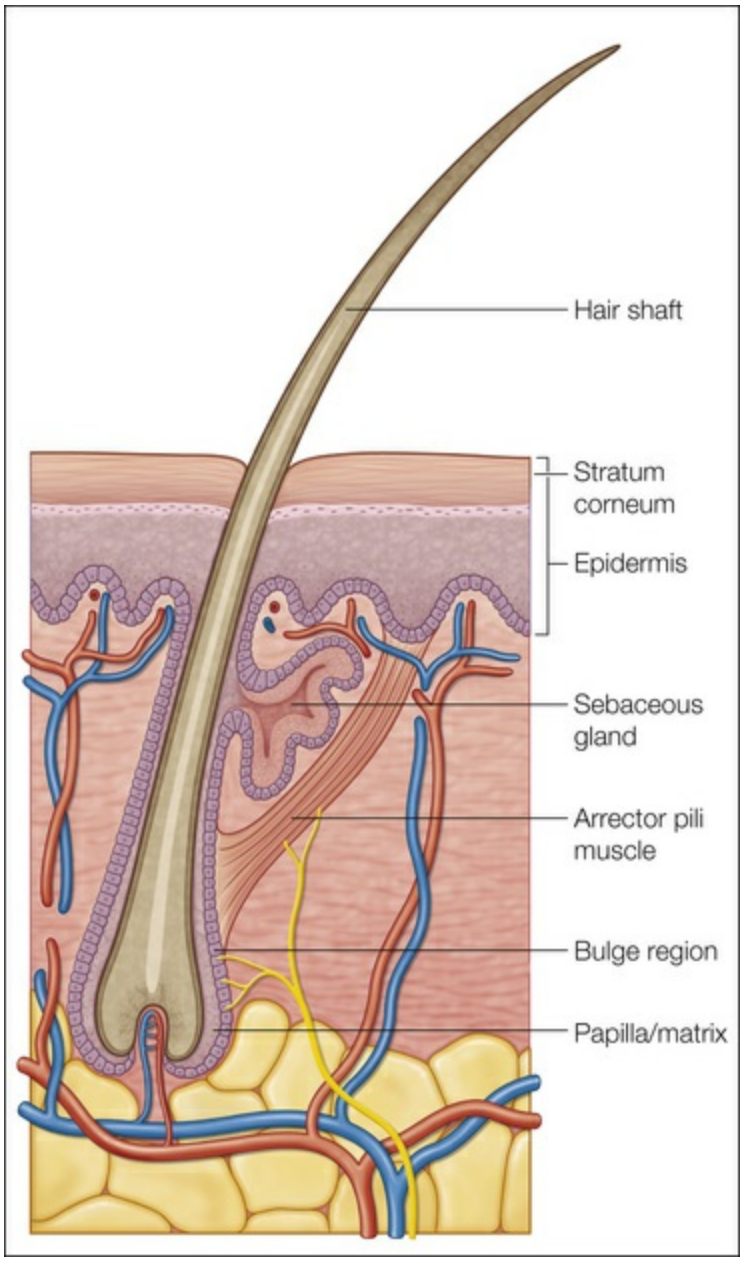


FIGURE 4.1 Hair follicle anatomy. Reproduced from Tsao SS, Hruza GJ. Laser hair removal. In: Robinson JK, Hanke CW, Sengelmann RD, Siegel DM, eds. Surgery of the Skin. Philadelphia, PA: Elsevier Mosby; 2005:575–588.

Every hair follicle is controlled by a programmed cycle that is dependent on the anatomic location. The hair cycle consists of anagen, catagen, and telogen phases. Anagen is characterized by a period of active growth in which the hair shaft lengthens. A catagen transition period follows in which the lower part of the hair follicle undergoes apoptosis. A resting period, telogen, then ensues, and regrowth occurs when anagen resumes. Hair regrowth (entry into another anagen cycle) is dependent on stem cells within or near the hair bulb matrix. Slow-cycling stem cells have also been found in the follicular bulge arising off the outer root sheath at the site of the arrector pili muscle attachment.

The main types of hair include lanugo, vellus, and terminal hairs. Lanugo hairs are fine hairs that cover a fetus and are shed in the neonatal period. Vellus

hairs are usually nonpigmented and have a diameter of approximately 30 to 50 μm. Terminal hair shafts range from 150 to 300 μm in diameter. The type of hair produced by an individual follicle is capable of change (e.g., vellus to terminal hair at puberty or terminal to vellus hair in androgenic alopecia).

The amount and type of pigment in the hair shaft determine hair color. Melanocytes produce two types of melanin: eumelanin, a brown-black pigment; and pheomelanin, a red pigment. Melanocytes are located in the upper portion of the hair bulb and outer root sheath of the infundibulum.

Definitions of what constitutes excessive or unwanted body hair depend on cultural mores but can usually be classified as either hypertrichosis or hirsutism. Hirsutism is the abnormal growth of terminal hair in women in male-pattern (androgen-dependent) sites, such as the face and chest. Hypertrichosis is excess hair growth at any body site that is not androgen-dependent. In addition, the use of grafts and flaps in skin surgery can often introduce hair to an area that causes a displeasing appearance or functional impairment.

Mechanism of laser hair removal

The theory of selective photothermolysis enables precise targeting of pigmented hair follicles by using the melanin of the hair shaft as a chromophore. Melanin has an absorbance spectrum that matches wavelengths in the red and near-infrared (IR) portion of the electromagnetic spectrum. To achieve permanent hair removal, the biologic "target" is the follicular stem cells located in the bulge region and/or dermal papilla. Due to the slight spatial separation of the chromophore and desired target, an extended theory of selective photothermolysis was proposed that requires diffusion of heat from the chromophore to the desired target for destruction. This requires a laser pulse duration that is longer in duration than if the actual chromophore and desired target are identical. Temporary LHR can result when the follicular stem cells are not completely destroyed, primarily through induction of a catagen-like state in pigmented hair follicles. Temporary LHR is much easier to achieve than permanent removal when using lower fluences. Long-term hair removal depends on hair color, skin color, and tolerated fluence. Approximately 15% to 30% long-term hair loss may be observed with each treatment when optimal treatment parameters are used (Fig. 4.2). A list of laser and light devices that are currently commercially available for hair removal is given in Table 4.1.


A
B
C



FIGURE 4.2 Laser hair removal (LHR) is safe and effective. **A**, The upper cutaneous lip of a hirsute female. **B**, Appearance of same subject following only three treatments with a long-pulsed 755-nm alexandrite laser used with a 12-mm spot size, 16 J/cm^2, 3-ms pulse duration, and dynamic cooling device (DCD) setting of 30/30/0. **C**, Axilla of an adult female. **D**, Following four treatments with a LPDL with a large spot size and vacuum-assisted suction. The fluence used was 12 J/cm^2 and the pulse duration was 60 ms. Both of the above subjects achieved excellent hair reduction and further benefit would likely be attained with additional treatments.

Table 4.1

Commercially available lasers and light sources for hair removal*

Laser/light source	Wavelength (nm)	System name	Pulse duration (ms)	Fluence (J/cm^2)	Spot size (mm)	Other features
Long-pulsed alexandrite	755	Apogee (Cynosure, Westford, MA, USA)	0.5–300	2–50	5–15	Cold air or integrated cooling, can add 1064-nm Nd:YAG module to form Apogee Elite
	—	Arion (Alma Laser, Buffalo Grove, IL, USA)	5–140	Up to 40	6–16	Cold air cooling
	—	Clarity (Lutronic, Gyeonggi-do, Korea)	0.35–300	Up to 60	2–20	Cryo or air cooling options, available with 1064-nm wavelength
	—	ClearScan ALX (Sciton, Palo Alto, CA, USA)	Up to 200	Up to 140	3, 6, and 30 × 30	Contact cooling
	—	Coolglide (Cutera, Brisbane, CA, USA)	0.1–300	5–300	10	Contact cooling
	—	Elite (Cynosure)	0.5–300	25–50	5–15	Cold air cooling, available with 1064-nm Nd:YAG, EliteMPX

						model can simultaneously treat with 755-nm alexandrite and 1064-nm Nd:YAG
	—	EpiCare LP/LPX (Light Age, Somerset, NJ, USA)	3–300	22–40	7–16	Dynamic cooling
	—	Excel HR	0.1–300	Up to 80	3–18	Chilled sapphire tip, comes with 1064-nm Nd:YAG
	—	GentleLASE Pro (Syneron-Candela, Wayland, MA, USA) GentleMax Pro (Syneron-Candela)	3 0.25–300	Up to 100 Up to 600	6–18 1.5–18	Dynamic cooling, comes with 1064-nm Nd:YAG
	—	Ultrawave 755/II/III (AMC Aesthetics and Advance Aesthetic Concepts, Plattsburgh, NY, USA)	Up to 100	Up to 125	Up to 16	Available with 532-, 1064-, and 1320-nm Nd:YAG
Diode	805	Advantage (Lutronic, Gyeonggi-do, Korea)	5–400	Up to 100	10 × 10, 10 × 30	Contact cooling
	800–810	F1 Diode (Opusmed, Canada)	15–40	Up to 40	5, 7	Chiller tip
	808, 980	Leda (Quantel Derma)	6–60	Up to 60	50 × 12, 10 × 12	Contact cooling
	810, 940	MeDioStar XT (Aesclepion)	5–500	Up to 90	6, 12	Integrated scanner with cold air cooling
	800	LightSheer Duet (Lumenis, Israel)	5–400	10–100, 4.5–12	9 × 9, 22 × 35	Chilltip for smaller handpiece, vacuum skin flattening for larger handpiece, 1060 nm wavelength available
	808	Clear & Brilliant Pelo (Solta Medical, Hayward, CA, USA)	4–100	Up to 100	50 × 15	Contact cooling
	810	Soprano XL (Alma Lasers, Buffalo Grove, IL, USA)	10–1350	Up to 120	12 × 10	Contact cooling
	810	Vectus (Cynosure)	5–300	Up to 100	12 × 12, 22 × 38	Contact cooling
Long-pulsed Nd:YAG	1064	—	—	—	—	—
	—	ClearScan YAG (Sciton)	0.3–200	Up to 400	3, 6, and 30 × 30	Contact cooling
	—	SP and XP Dynamis, XP Focus, XP Max (Fotona)	0.1–50	Up to 300	2–10	N/A
	—	GentleYAG Pro (Syneron-Candela, Wayland, MA, USA)	0.25–300	Up to 600	1.5–18	Dynamic cooling
	—	LightPod Neo (Aerolase, Tarrytown, NY, USA)	0.65–1.5	Up to 312	2	—
	—	MultiFlex (Ellipse, UK)	N/A	Up to 600	1.5–5	Contact cooling
	—	Mydon (Quante Dermal)	0.5–90	10–450	1.5–10	Equipped with IPL device
	—	NaturaLase 1064/LP (Focus Medical, Bethel, CT, USA)	0.5–100	Up to 400	3–15	Integrated air cooling
	—	Profile (Sciton)	0.1–10	Up to	n/a	Integrated air cooling

			000	75		
	—	SmartEpil (Deka, Italy)	Up to 20	11	2.5, 4, 5, 6	Contact cooling, 2940 nm Er:YAG and 410-1400 nm flashlamp in same device
	—	Synchro_FT (Deka)	2–30	Up to 50	2.5–13	Available with IPL handpiece
	—	Ultrawave II/III (AMC Aesthetics, and Advance Aesthetic Concepts)	Up to 300	5–500	Up to 12	Pulsed cryogen cooling
	—	Varia (CoolTouch, Roseville, CA, USA)	0.6	Up to 500	2–10	Dynamic cryogen cooling
IPL sources	520–1200	Axiom (Viora, Jersey City, NJ, USA)	25–75 and 2.2–12.5	Up to 39	50 × 25, 35 × 15, 20 × 10	Built-in cooling system
	420–1400	BBL (Sciton)	Up to 200	Up to 30	15 × 45	Built-in cooling system
	560–590	Cynergy (Cynosure)	0.3–300	Up to 600	n/a	Built-in cooling system
	400–1200	Duet/SkinStation/ SpaTouch II (Radiancy, Orangeburg, NY, USA)	3–10	35	22 × 55	—
	600–950	Ellipse I2PL/MultiFlex (Ellipse)	2.5–88.5	4–26	10 × 48	—
	650–950	Harmony XL (Alma Lasers)	30–50	Up to 40	30 × 30	MultiFlex model with long-pulsed Nd:YAG
	530–1200	iPulse (Dermavista, Birmingham, AL, USA)	10–110	Up to 20	8.9 cm^2	Available with 755-nm alexandrite and 1064- and 1320-nm Nd:YAG
	390–1200	Med Flash II (General Project, Italy)	Up to 100	Up to 45	n/a	Air cooling
	525–1200	Icon/StarLux, R, Rs (Palomar, Burlington, MA, USA)	5–500	Up to 70	28 × 12, 46 × 16	—
	500–1200	MiniSilk_FT (Deka)	3–8	Up to 160	48 × 13, 23 × 13	1064-nm Nd:YAG handpiece
	400–1200	Mistral (Radiancy)	Up to 80	4–15	25 × 50, 13 × 50, 13 × 35, 12 × 12	Contact cooling
	640–1400	NannoLight MP50 (Sybaritic, Minneapolis, MN, USA)	1–30	2.8–50	40 × 8	Nd:YAG handpiece, optional cooling
	640–1200	NaturaLight (Solamed, Tampa, FL, USA)	Up to 500	Up to 50	10 × 40	—
	750–1100	Solera Opus (Cutera)	Auto	3–24	10 × 30	—
	550–950	PhotoSilk Plus (Deka)	Up to 30	10–340	21 × 10, 46 × 10, 46 × 18	—
	770–1100	ProWave (Cutera)	Auto	5–35	10 × 30	Nd:YAG handpiece
	500–1200	Quadra Q4 (DermaMed, Lenni, PA, USA)	48	10–20	33 × 15	—

	695–1200	Quantum HR (Lumenis)	15–100	25–45	34 × 8	—
	560–950	SmoothCool (Eclipse, Dallas, TX, USA)	1–60	10–45	8 × 34	Built-in cooling system
	530–1200	Trios (Viora)	25	Up to 22	15 × 50	Automatic temperature control system
Fluorescent pulsed light	615–920	OmniLight/NovaLight (American Medical Bio Care, Newport Beach, CA, USA)	2–500	Up to 90	7 × 15, 10 × 20, 30 × 30	Sapphire tip cooling
Optical energy combined with RF electrical energy	580–980	eMax/eLight (Syneron)	Up to 100	Up to 50 optical; up to 50 J/cm^3 RF	12 × 15	Contact cooling
Diode combined with RF electrical energy	800	eLaser (Syneron)	Up to 100	Up to 50 optical; up to 50 J/cm^3 RF	12 × 15	Contact cooling
	810	MeDioStar Effect (Aesclepion)	Up to 500	Up to 90	10, 12, 14	Acoustic wave technology, integrated scanner with cold air cooling device, 940 nm simultaneously
Home-use devices	—	no!no!hair (Radiancy, Orangeburg, NY, USA)	—	—	—	Thermal-based device
	—	—	—	—	—	—
	—	Silkn SensEpil (Skinnovations, Israel)	—	—	—	IPL-based, devices with finite number of pulses
	—	Viss IPL (Viss Beauty, Korea)	—	—	—	IPL-based, finite number of pulses
	—	Tria Laser 3.0 (Tria Beauty, Pleasanton, CA, USA)	—	—	—	Diode laser, low, medium and high fluences
	—	SpaTouch Elite (Radiancy)	—	—	—	IPL and thermal
	—	Kona (Radiancy)	—	—	—	IPL and thermal

*This table is intended only as a reference aid. The authors have made every attempt to provide an exhaustive list of available devices for LHR but do not guarantee comprehensiveness.

IPL, Intense-pulsed light; *RF*, radiofrequency.

Key factors in optimizing treatment

LHR has revolutionized the ability to eliminate unwanted hair temporarily and permanently in many individuals of all skin colors. Proper patient selection, preoperative preparation, informed consent, understanding of the principles of laser safety, and laser and light source selection are key to the success of laser treatment. An understanding of hair anatomy, growth and physiology, together with a thorough understanding of laser–tissue interaction, in particular within the context of choosing optimal laser parameters for effective LHR, should be acquired before using lasers for hair removal.

Patient selection

A focused medical history, physical examination, and informed consent, including setting realistic expectations and potential risks, should be performed prior to any laser treatment (Box 4.1). Patients with evidence of endocrine or menstrual dysfunction should be appropriately worked up. Similarly, patients with an explosive onset of hypertrichosis should be evaluated for paraneoplastic etiologies. Treatment of a pregnant woman for nonurgent conditions is discouraged by the authors, although there is no evidence suggesting a potential risk to pregnant women undergoing LHR. The past medical history should be reviewed to identify patients with photosensitive conditions, such as autoimmune connective tissue disorders, or disorders prone to the Koebner phenomenon. A history of recurrent cutaneous infections at or in the vicinity of the treatment area might warrant the use of prophylactic medications. Any past history of keloid or hypertrophic scar formation should be elicited as well. Previous hair removal methods, including past laser treatments, should be reviewed. Any methods of hair shaft epilation (e.g., waxing or tweezing) that entirely remove the target chromophore render LHR less effective for at least 2 weeks. Although there is little evidence for the time frame a patient must wait after complete epilation of the hair shaft and laser treatment, we recommend a minimum of 6 weeks. Shaving and depilatory creams can be used up to the day of laser treatment because they do not remove the entire hair shaft.

Case Study 1

A 27-year-old Hispanic female with Fitzpatrick skin type IV presents to you for hair removal on the "beard area." She has been treated five times with a diode laser over the course of 2 years at a local spa and notes only a minimal reduction of hair. On review of systems, you discover that the patient has had a history of irregular menses and periodically flaring acne. She does not see a gynecologist.

Although it appears that the patient is responding poorly to laser treatment, a thorough history reveals that the patient has clinical and historical evidence of hormonal dysfunction. This imbalance may be driving the conversion of vellus hair to terminal hair and can make it appear that LHR treatments are ineffective, when in reality the patient is responding to treatment but is creating new hair follicles.

Pearl 1

It is imperative to counsel the patient not to partake in any epilation activities that remove the entire hair shaft. Shaving or using a chemical depilatory prior to treatment is acceptable but waxing or plucking will be counteractive to the laser treatments. A 2-week interval after such procedures is recommended for improved efficacy.

Box 4.1

Pertinent medical history for laser and pulsed light hair removal

• Presence of conditions that may cause hypertrichosis:

– Hormonal

– Familial

– Drugs (i.e., corticosteroids, hormones, immunosuppressives, self or spousal use of minoxidil)

– Tumor

– History of local or recurrent skin infection

– History of herpes simplex, especially perioral

– History of herpes genitalis, important when treating the pubic or bikini area

– History of keloids/hypertrophic scarring

– History of koebnerizing skin disorders, such as vitiligo and psoriasis

– Previous treatment modalities—method, frequency, and date of last treatment, as well as response

– Recent suntan or exposure to tanning or light cabinet

– Onset of hair regrowth (recent)

– Tattoos or nevi present

– Patient's expectations

– Patient's hobbies or habits which might interfere with treatment

- Present medications:

– Photosensitizing medications

A medication history should be obtained. The use of any photosensitizing medications or over-the-counter supplements should be held before treatment. Topical retinoids used in the treatment area should be discontinued 1 to 2 days prior to treatment. Finally, the patient's reaction to unprotected sun exposure (Fitzpatrick skin phototype) should be elicited as part of the history.

The physical exam should corroborate the patient's Fitzpatrick skin phototype. This will help to determine which lasers and light sources are safe to use for that patient (see Table 4.1) because epidermal melanin in darkly pigmented patients competes with the melanin within hair follicles as a chromophore. Importantly, every patient should always be evaluated for the presence of a tan and, if present, laser treatment should be delayed or the treatment parameters appropriately adjusted until the tan has faded. Finally, the patient's hair color should be noted as the chromophore for LHR is melanin. Black and brown terminal hairs typically contain sufficient amount of melanin to serve as a chromophore for LHR. In contrast the lack of melanin, paucity of melanin or presence of eumelanin in the hair follicle, which clinically correlates with white, gray, or red/blonde hair, respectively, is predictive of a poor response to LHR (Fig. 4.3). For patients with little to no melanin in their hair follicles, attempts have been made to use exogenous chromophores that can be topically delivered to the hair follicles, thereby making the removal of white, gray, red, and blonde hair hypothetically possible. This concept was first demonstrated with a topical carbon solution dissolved in mineral oil. However, we have noticed very little long-term hair reduction efficacy of topical chromophores in our experience. The coarseness and density of hair are also important to note because these factors will influence parameter settings (see later).

Pearl 2

Treatment on tanned patients should be delayed until the tan fades. Risk of pigmentary alteration is significantly higher in these patients.

Pearl 3

Patients with white, gray, or blonde hair are currently not appropriate candidates for LHR. Other methods of epilation should be encouraged.



FIGURE 4.3 Effective LHR can be obtained for dark, pigmented hairs but not for white hairs: (**A**) before and (**B**) after treatment.

Informed consent

Informed consent requires a review of the potential risks of LHR, which include, but are not limited to, temporary and permanent hypopigmentation or hyperpigmentation, blister formation, scar formation, ulceration, hive-like response, bruising, infection, acne flare, and folliculitis. For those patients with Fitzpatrick skin type IV or greater or of Mediterranean, Middle Eastern, Asian, or South Asian descent, the low risk of paradoxical hypertrichosis (conversion of vellus hairs to thicker, more obvious terminal hairs), especially when treating the lateral face and jaw, should be reviewed. Patients should be counseled that permanent and complete hair removal is not likely but that, with multiple treatments, significant long-term reduction can be achieved. Hirsute women with hormonal abnormalities, such as polycystic ovarian syndrome, may require continued maintenance therapy and should be advised of this possibility. Procedural pain is expected with LHR but can be minimized with topical anesthetics. Erythema and edema are also expected with treatment and may last up to 1 week. Patients should be aware of the need for strict sun avoidance before and after each treatment.

Case Study 2

A 32-year-old Egyptian female presents for LHR of the lateral preauricular face. On physical exam, she is a Fitzpatrick skin type V with fine, dark vellus hairs in the area of interest.

This patient is a challenge for a variety of reasons (dark skin type, caliber of hair to be treated). Importantly, it is critical for the laser surgeon to also review the rare risk of paradoxical hypertrichosis (see previously). Paradoxical hypertrichosis is a poorly understood phenomenon in which laser stimulates hair growth or a change in hair type from vellus to terminal hairs. This produces an obvious worsening in the appearance of the affected hairs in a cosmetically sensitive area (i.e., the face). Although challenging, these increased hairs can be treated with further hair removal but they may be more resistant to therapy.

Preoperative preparation and laser safety

The need for topical anesthesia is variable among patients and anatomic sites. Various topical anesthetics, including lidocaine, lidocaine/prilocaine, and other amide/ester anesthetic combinations, can be used to diminish the procedural discomfort and should be applied 30 minutes to 1 hour before treatment under occlusion. Care should be taken when using lidocaine or prilocaine to apply these medications to a limited area to diminish the risk of lidocaine toxicity or methemoglobulinemia, respectively. Deaths have resulted from lidocaine toxicity resulting from occlusion of the back, as well as lower extremities, with high concentrations of compounded topical lidocaine. Likewise, systemic toxicity can occur with the use of any topical anesthetic in large amounts.

Pearl 4

Occlusion increases the absorption of topical medications by at least an order of magnitude. Lidocaine is a cardiotoxic medication, and prilocaine can convert hemoglobin into methemoglobulin. Large areas, such as the back or legs, should have topical anesthesia applied with caution.

Patients should be placed in a room with a treatment chair that makes the desired treatment area easily accessible. The room should be adequately cooled to keep the laser device from overheating and be free of any hanging mirrors or uncovered windows. A fire extinguisher should be readily available. If possible, supplemental oxygen should be turned off when performing laser treatments. Having a vacuum device on hand during treatment can minimize the plume and unpleasant odor created by each laser pulse. Because the retina contains melanin that can be damaged by wavelengths in the red and near-IR range, proper eye protection is absolutely critical for both the patient and laser surgeon. Goggles are not interchangeable between lasers or intense pulsed-light (IPL) devices of different wavelengths. Furthermore, because of the risk of retinal damage from the deeply penetrating wavelengths used for LHR, one should never treat a patient for LHR within the bony orbit.

Case Study 3

A 35-year-old female with Fitzpatrick skin type II and jet-black hair presents to you for LHR. During the consultation, she states her primary concern is that she would like to have her eyebrows shaped permanently. She is inconvenienced by her current regimen of waxing every several weeks.

The patient is an ideal candidate for LHR with her fair skin and dark hair. Almost any hair removal laser would be appropriate for use. The issue of concern in this case is the location of treatment. Caution must be taken when treating near the eye because there is a risk of damage to retinal pigment.

Device variables

Wavelength

The chromophore for LHR is melanin. Within the hair follicle, melanin is principally located within the hair shaft, although the outer root sheath and matrix area also contain melanin. Melanin is capable of functioning as a chromophore for wavelengths in the red and near-IR portion of the electromagnetic spectrum, and can be targeted by ruby, alexandrite, diode, and neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers, as well as IPL devices.

The long-pulsed ruby laser (694 nm) was the first device used to selectively target hair follicles, resulting in long-term hair loss. The long-pulsed ruby laser can be safely used in Fitzpatrick skin phototypes I to III. Table 4.1 lists the long-pulsed ruby lasers that are commercially available.

The long-pulsed alexandrite (755 nm) laser has been shown to be effective for long-term hair removal in multiple studies. The long-pulsed alexandrite laser can be safely used in Fitzpatrick skin phototypes I to IV, although some experts limit the use of the long-pulsed alexandrite laser to Fitzpatrick skin phototypes I to III. A few studies have demonstrated the safety of the long-pulsed alexandrite laser in a large cohort of patients with Fitzpatrick skin phototypes IV to VI. Combination treatment of alexandrite and Nd:YAG lasers provides no added benefit over the alexandrite laser alone. The commercially available long-pulsed alexandrite devices are summarized in Table 4.1.

The long-pulsed diode laser (LPDL, 800 to 810 nm) has also been extensively used for LHR. The diode laser can be safely used in patients with Fitzpatrick skin phototypes I to V and has good long-term efficacy for LHR. A 1060-nm diode laser has also demonstrated long-term efficacy in all Fitzpatrick skin phototypes.

The long-pulsed Nd:YAG laser has been thought to offer the best combination of safety and efficacy for Fitzpatrick skin phototype VI patients. Long-term hair reduction with 18-month follow-up showed 73.6% clearance following four treatments at 2-month intervals.

IPL is composed of polychromatic, noncoherent light ranging from 400 to 1200 nm. Various filters can be used to target particular chromophores, including melanin. One study of patients treated with a single IPL session reported 75% hair removal 1 year after treatment. Two studies providing a

head-to-head comparison of IPL versus either the long-pulsed alexandrite laser or Nd:YAG laser both found the IPL to be inferior to laser devices for hair removal. In contrast, a study of hirsute women, some with a diagnosis of polycystic ovarian syndrome, who underwent a split-face treatment with six IPL or LPDL showed statistically equivalent reductions in hair counts at 1 (77% vs. 68%, respectively), 3 (53% vs. 60%, respectively), and 6 months (40% vs. 34%, respectively) after the final treatment.

Pearl 5

One should always evaluate the patient's Fitzpatrick skin type when evaluating a patient for LHR. Darker skin types require longer wavelengths, which pose a lower risk of side effects from the absorption of energy by epidermal melanin.

Fluence

Fluence is defined as the amount of energy delivered per unit area and is expressed as J/cm^2. Higher fluences have been correlated with greater permanent hair removal but are also more likely to cause untoward side effects. Recommended treatment fluences are often provided with each individual laser device for nonexperienced operators. However, a more appropriate method of determining the optimal treatment fluence for a given patient is to evaluate for the desired clinical end point of perifollicular erythema and edema seen within a few minutes of treatment (Fig. 4.4). The highest possible tolerated fluence that yields this end point without any adverse effects is the best fluence for treatment. Fluences that cause epidermal disruption are too high and should be reduced.

Pearl 6

When treating a patient for LHR for the first time, it may be prudent to try several test spots at varying fluences to determine the optimal settings. The highest tolerable fluence without epidermal damage will yield the greatest amount of hair clearance per treatment.

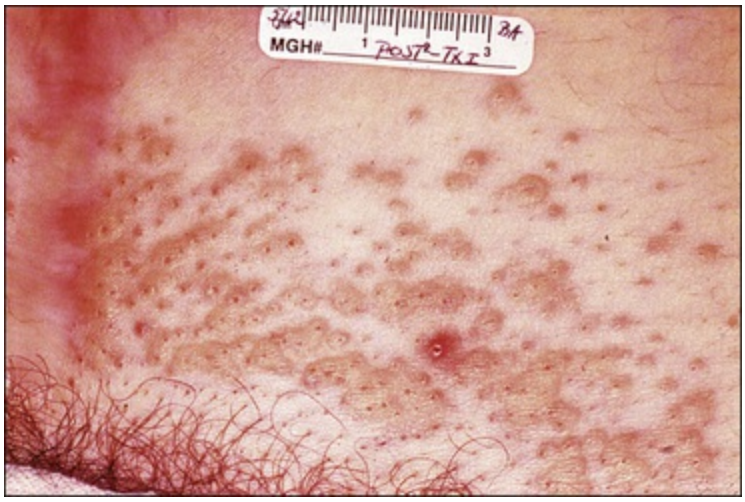


FIGURE 4.4 Formation of perifollicular eythema and edema immediately after laser treatment.

Pulse duration

Pulse duration is defined as the duration in seconds of laser exposure. The theory of selective photothermolysis enables the laser surgeon to select an optimal pulse duration based on the thermal relaxation time (TRT). Terminal hairs are approximately 300 μm in diameter, and thus the calculated TRT of a terminal hair follicle is approximately 100 ms. However, unlike many other laser applications, the hair follicle is distinct in that there is a spatial separation of the chromophore (melanin) within the hair shaft and the biologic "target" stem cells in the bulge and bulb areas of the follicle. The expanded theory of selective photothermolysis takes this spatial separation into account and proposes a thermal damage time (TDT), which is longer than the TRT. Shorter pulse widths are also capable of removing hair, and it is unclear which is more effective in producing permanent hair removal. Longer pulse widths are likely more selective for melanin within the hair follicle and can minimize epidermal damage as the pulse widths are greater than the TRT of the melanosomes in epidermal keratinocytes and melanocytes.

Pearl 7

When treating darker Fitzpatrick skin types, a longer pulse duration is preferred because the pulse duration exceeds the TRT of the epidermal melanin and minimizes the risk of epidermal damage.

Spot size

The spot size is the diameter in millimeters of the laser beam. As photons within a laser beam penetrate the dermis they are scattered by collagen fibers, and those that are scattered outside the area of the laser beam are essentially wasted. Photons are more likely to be scattered outside of the beam area for smaller spot sizes, whereas in a larger spot size the photons are likely to remain

within the beam area following scatter. A double-blind, randomized controlled trial of a long-pulsed alexandrite laser for LHR of the axillary region comparing 18- and 12-mm spot sizes at otherwise identical treatment parameters showed a 10% greater reduction in hair counts with the larger spot size. A prospective study using an LPDL with a large 22 × 35 mm handpiece at low fluences, and no skin cooling was shown to have similar long-term hair removal efficacy to published studies of LPDLs with smaller spot sizes, using higher fluences and skin cooling. Thus larger spot sizes are preferable to smaller spot sizes.

Pearl 8

Using the largest possible spot size allows for optimal penetration and minimizes the number of pulses it takes to cover a treatment area, thereby translating to faster treatment courses.

Skin cooling

The presence of epidermal melanin, particularly in darker skin types, presents a competing chromophore to hair follicle melanin, which can be damaged during LHR (Fig. 4.5). Cooling of the skin surface is used to minimize epidermal damage as well as pain, while permitting treatment with higher fluences. All of the skin-cooling methods function by acting as a heat sink and removing heat from the skin surface. The least effective type of cooling is the use of an aqueous cold gel, which passively extracts heat from the skin and then is not capable of further skin cooling. Alternatively, cooling with forced chilled air can provide cooling to the skin before, during, and after a laser pulse. Currently, most of the available LHR devices have a built-in skin-cooling system, which consists of either contact cooling or dynamic cooling with a cryogen spray. Contact cooling, usually with a sapphire tip, provides skin cooling just before and during a laser pulse. It is most useful for treatments with longer pulse durations (>10 ms). Dynamic cooling with cryogen liquid spray precools the skin with a millisecond spray of cryogen just before the laser pulse. A second spray can be delivered just after the laser pulse for postcooling, but parallel cooling during the laser pulse is not possible because the cryogen spray interferes with the laser beam. Dynamic cooling is best suited for use with pulse durations shorter than 5 ms.

Pearl 9

Skin cooling is beneficial for minimizing epidermal damage and treatment-associated pain. However, cooling can be overdone and result in pigmentary alterations, particularly with cryogen liquid spray.



FIGURE 4.5 Inadequate contact cooling resulting in postinflammatory hypopigmentation in a patient with type V skin. Photograph courtesy of Nathan Uebelhoer.

Postprocedure care

It is expected for the patient to have perifollicular erythema and edema in the treatment area following LHR. This generally persists for 2 days but can last for up to 1 week. Ice and application of a topical corticosteroid can be used to shorten the duration of these undesired clinical findings. Patients will often find that a single treatment of LHR with shorter pulse durations results in nearly total epilation of the hair follicles in the treatment area. It is important to counsel the patient that a majority of these hairs will likely regrow, and this is not considered a treatment failure. In general, only approximately 15% of hairs are permanently removed with each laser treatment. On the other hand, LHR treatments with longer pulse durations may leave behind many hairs that appear to "grow" following treatment. It is important to reassure the patient that these "growing" hairs are dislodged from the hair follicle and require 1 to 2 weeks to be completely shed. Nearly any method of epilation can be used to hasten their removal.

The importance of strict sun precaution following LHR treatments cannot be overemphasized. This can be achieved by the use of topical sunscreens, ultraviolet light impermeable garments, and, most importantly, sun avoidance.

Pearl 10

Beyond sun protection factor30 (SPF30), higher sun protection factor (SPF) values do not necessarily correlate with increased protection from the sun. The SPF value of a product only reflects its protection from ultraviolet B (UVB) rays. It is far more important that the product contain broad-spectrum protection, including ultraviolet A (UVA) rays.

Long-term efficacy

Permanent hair removal was evident as early as the seminal hair removal trial from the Wellman Center involving a single treatment with the normal mode ruby laser. Seven of the 13 original subjects were evaluated at 2-year follow-up. Of the seven subjects, four had evidence of persistent permanent hair reduction at 2-year follow-up, whereas three subjects experienced complete regrowth. Follow-up of 18 out of the 50 original study subjects treated with an LPDL showed a 25% to 33% and 36% to 46% hair reduction at a mean follow-up of 20 months after one or two treatments (9-mm spot size, pulse duration of 5 to 20 ms, fluences of 15 to 40 J/cm^2, single or triple pulsed), respectively. A head-to-head trial comparing an LPDL to a long-pulsed alexandrite laser found a 49% to 94% hair reduction at 1-year follow-up after four treatments (9-mm spot size, pulse duration of 20 ms, fluences of 12 to 40 J/cm^2) with the LPDL in 15 subjects. Similar results were achieved with the alexandrite laser used in this study. Fifteen of 20 subjects with Fitzpatrick skin phototypes III to IV treated with a long-pulsed alexandrite laser (12- and 18-mm spot size, 3-ms pulse duration, and fluences of 20 or 40 J/cm^2) or a long-pulsed Nd:YAG laser (12-mm spot size, 3-ms pulse duration, and fluence of 40 J/cm^2) for four sessions at 8-week intervals showed 76% to 84% and 74% hair reduction 18 months after the last treatment, respectively. Another head-to-head trial of a high-fluence LPDL (9-mm spot size, pulse duration of 30 ms, fluences of 20 to 50 J/cm^2) versus a low-fluence LPDL (12 × 10 mm spot size, pulse duration of 20 ms, fluences of 5 to 10 J/cm^2) in 22 subjects showed similar, 94% and 90% hair reduction at 18-month follow-up following five treatments spaced 6 to 8 weeks apart, respectively. Finally, the authors reported statistically significant hair clearance, 54% and 42%, at 6- and 15-month follow-up visits following three monthly treatments using a LPDL with a large handpiece in the largest prospective trial to date. Remaining hairs were found to also grow back less thick and lighter.

Complications

The most common complications of LHR are epidermal damage (Fig. 4.6) and pigmentary alterations, including hyperpigmentation and hypopigmentation (Fig. 4.7). This may result from selecting a nonoptimal wavelength, pulse duration, or fluence, using inadequate epidermal cooling, or treating a tanned patient (Fig. 4.8). Pigmentary alterations may also occur even when optimal treatment parameters are used. These changes are often transient and improve with time, although permanent hypopigmentation can occur (see Fig. 4.7B). Zones of untreated hairs can result from a lack of overlapping between laser pulses (Fig. 4.9). Scarring is an exceedingly rare complication but can occur when an inappropriate wavelength is used on skin of color, excessive fluences, and/or pulse stacking are used.



FIGURE 4.6 Epidermal damage with focal crusting resulting from excessive laser fluence.



FIGURE 4.7 Example of LHR-induced hyperpigmentation (**A**) and permanent hypopigmentation (**B**).



FIGURE 4.8 Treatment of recently tanned skin resulted in development of hypopigmentation.



FIGURE 4.9 Zones of untreated skin resulting from lack of appropriate overlapping.

Treatment of the lateral cheeks and chin area, or less commonly other areas, may result in the induction of terminal hairs, a phenomenon known as paradoxical hypertrichosis (Fig. 4.10). This has been reported to occur more

commonly in females of Mediterranean, Middle Eastern, Asian and South Asian descent. The exact mechanism remains uncharacterized, but it is thought that subtherapeutic laser fluences may lead to the stimulation of hair growth.



FIGURE 4.10 Paradoxical hypertrichosis. Conversion of fine,

vellus-like hairs (**A**) to terminal dark hairs (**B**) after a single LHR treatment.

Caution should be exercised to avoid treatment over tattoos and nevi, particularly atypical nevi. Treatment of other dermatologic conditions, such as vascular birthmarks, can cause inadvertent permanent hair reduction.

A review of legal databases showed that LHR was the most commonly litigated laser procedure among malpractice cases, and that nonphysician operators in the medical spa setting comprised the majority of litigated cases.

Conclusion

Future directions

Advances in pain control

A recent technique to reduce LHR-associated pain is pneumatic skin flattening (PSF). PSF works by coupling a vacuum chamber to generate negative pressure and to flatten the skin against the handpiece treatment window. Based on the gate theory of pain transmission, it stimulates pressure receptors in the skin immediately prior to firing of the laser pulse, thereby blocking activation of pain fibers. PSF has been incorporated into commercially available lasers (see Table 4.1). A study of LHR using a LPDL with a large spot size and vacuum-assisted suction showed that the majority of subjects reported feeling no pain at all or up to moderate pain without the use of skin cooling or topical anesthetics. Notably, none of the subjects in the study reported experiencing severe or intolerable pain.

Home-use laser and light source devices for hair removal

In recent years, a number of devices have been developed that seek to provide patients with the ability to achieve energy-based hair removal at home. These devices are based on IPL, laser, and thermal technologies that target the hair follicle for destruction. Devices that have 510(k) clearance by the FDA in the United States are listed in Table 4.1. Similar technologies are also being used by a variety of other home-use devices that do not currently have FDA 510(k) clearance.

The evidence behind such devices is scant and limited to small noncontrolled studies. A study demonstrated that a thermally based, home-use device was no better than shaving in removing hair, reducing hair density, or slowing hair regrowth. In addition, the risk for devastating eye injuries with improper use of laser- and IPL-based devices and lack of medical training raises a dilemma of how much autonomy a patient should have with potentially harmful devices. Nonetheless, the appeal of having a personal device to remove unwanted hair in the privacy of one's home without the expense and inconvenience of multiple dermatologist or spa visits will likely drive the development of additional home-use devices.

Alternative technologies for hair removal

Photodynamic therapy (PDT) with aminolevulinic acid (ALA) has been shown in a small pilot study to result in up to 40% hair reduction with a single treatment, although wax epilation was performed prior to treatment in this study.

Electro-optical synergy (ELOS) technology combines electrical (conducted radiofrequency [RF]) and optical (laser/light) energies. A handful of devices based on this technology have been produced (see Table 4.1). The theory behind ELOS is based on the optical component (laser or IPL) heating the hair shaft, which then is thought to concentrate the bipolar RF energy to the surrounding hair follicle. Based on this combination, lower fluences are needed for the optical component, thereby suggesting it might be well tolerated in all Fitzpatrick skin phototypes, and potentially effective in the removal of white and poorly pigmented hair. A study of 40 patients (Fitzpatrick skin phenotypes II to V) with varied facial and nonfacial hair colors were treated with combined IPL/RF ELOS technology. An average clearance of 75% was observed at 18 months following four treatments. No significant adverse sequelae were noted, and there were no treatment differences between patients of varying skin types or hair color. Pretreatment with ALA prior to use of a combined IPL and RF device has been shown to further augment the removal of terminal white hairs. A novel device using Total Reflection Amplification of Spontaneous Emission of Radiation (TRASER) has been shown to produce similar clinical and histopathologic effects as LHR in a small observational study.

In conclusion, hair removal has made a dramatic shift from an art to science based on the theory of selective photothermolysis. Since the first reports of selective hair removal in 1996 by Anderson and colleagues, there has been a tremendous explosion in the number of devices used for LHR, making LHR the most commonly requested cosmetic procedure in the world. This chapter provides the reader with the fundamentals of hair follicle anatomy and physiology, points for patient selection and preoperative preparation, principles of laser safety, an introduction to the various laser/light devices, and a discussion of laser–tissue interactions that are vital to optimizing treatment efficacy while minimizing complications and side effects.

Check online videos (Video 4.1 and Video 4.2).

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5

Nonablative laser and light skin rejuvenation

Travis W. Blalock, E. Victor Ross



Summary and Key Features

- Nonablative skin resurfacing is a safe and effective means of improving many aspects of photoaged skin.
- Although nonablative skin resurfacing provides modest results, it also provides minimal downtime.
- Nonablative resurfacing alters cellular and noncellular components of the skin without causing an open wound.
- Patient selection requires careful consideration of medical factors, as well as patient expectations.
- Nonablative modalities rarely require more than topical anesthesia.
- When performed with thoughtful consideration, complications are rare.
- Photodynamic therapy has been used to maximize laser–tissue interactions and subsequent improvement in photoaging.
- Treatment of types IV to VI skin requires adjustment of laser parameters to minimize pigment alteration.
- Patients can generally return to their normal activities in 1 to 3 days following treatment with nonablative modalities.
- For patients with limited available downtime, multiple treatments 2 to 3

months apart may provide improved results.

Introduction

With the advancement of laser and non-laser light sources, the focus of skin rejuvenation is optimizing efficacy while minimizing recovery times. The gold standard for rejuvenation, at least for fine wrinkles, has been ablative modalities. Although ablative tools can achieve predictable cosmetic enhancement, the risks of scarring, infection, dyspigmentation, and prolonged recovery times make these modalities less attractive. Patients increasingly try to balance efficacy of skin rejuvenation within the context of downtime. Nonablative skin rejuvenation (NAR) normally mitigates the need for injectable anesthesia and can often be performed with only topical anesthesia or no anesthesia at all. Thus nonablative modalities have enjoyed a greater role in skin rejuvenation.

A clear definition of nonablative skin rejuvenation is important because the term is sometimes used haphazardly. In its purest form, nonablative rejuvenation improves skin quality without physical removal or vaporization of the skin. Ablative modalities, via vaporization, remove a portion, or all, of the epidermis and sometimes may remove parts of the dermis. This chapter focuses on nonfractional methods of nonablative skin rejuvenation. In addition to light devices, nonablative radiofrequency (RF)-based technologies will also be included in our discussion.

The dermis (and/or deeper epidermis) can be selectively damaged by four basic approaches:

1. Targeting discrete chromophores in the dermis and/or at the dermal–epidermal junction.

2. Using mid-infrared lasers in the range of 1.3- to 1.55-μm wavelengths, in which water absorption is weak enough that relatively deep beam penetration is allowed (there is only 50% beam attenuation at depths of 300 to 1500 μm).

3. Applying RF energy from the surface with cooled electrodes such that temperatures are greater in the dermis and fat versus the epidermis.

4. In addition, beyond nonablative fractional lasers (covered in Chapter 6), RF needle devices can, with uninsulated or insulated needles, deliver direct focal injuries to the skin. These devices can perform multiple roles, from skin tightening (as outlined in Chapter 9), to improvement in more superficial tone and texture (primarily dependent on the depth of the needle insertions).

Treatment of photodamage can be divided into various categories, and treatment protocols are based on a logical approach founded on the laser–tissue or RF–tissue interactions delineated previously. The goal should be to maximize skin rejuvenation from reducing telangiectasia and lentigines to enhancing

dermal remodeling.

The laser and non-laser systems used for nonablative rejuvenation are a heterogeneous group of devices that emit wavelengths in the visible (400 to 760 nm), near-infrared (760 to 1400 nm), or mid-infrared (1.4 to 1.6 μm) ranges, intense pulsed-light (IPL) devices, as well as light-emitting diodes (LEDs), and RF devices (Box 5.1). Each of these tools can induce dermal remodeling, as well as target other components, without epidermal ablation. Most investigators believe that photothermal heating of the dermis: (1) increases collagen production by fibroblasts and (2) induces dermal matrix remodeling by altering glycosaminoglycans, as well as other components of the dermal matrix. Others believe that the laser/light interaction with molecular cellular components alters the cellular function of enzymes, as well as cellular structural components. Altering the different components of cells, from enzymes to cellular wall constituents to nucleic acids, may then alter the environment and productivity of a given cell.

Box 5.1

Devices used in nonablative skin resurfacing

- Visible light/vascular lasers
  - 532-nm potassium titanyl phosphate (KTP)
  - 585/595-nm pulsed dye
- Near-infrared lasers
  - 1064-nm Q-switched neodymium:yttrium-aluminum-garnet (Nd:YAG)
  - 1064-nm long-pulsed Nd:YAG
  - 1320-nm Nd:YAG
- Mid-infrared lasers
  - 1450-nm diode
  - 1540-nm erbium:glass
- Intense pulsed light (IPL) (500–1200 nm)
- Radiofrequency (RF) systems

- Light-emitting diode (LED)

Photodynamic therapy (PDT) with aminolevulinic acid (ALA) has been shown to augment the effects of laser and other light sources. Multiple laser and light sources have been used for photoactivation of protoporphyrin IX, leading to improved skin rejuvenation (Fig. 5.1).

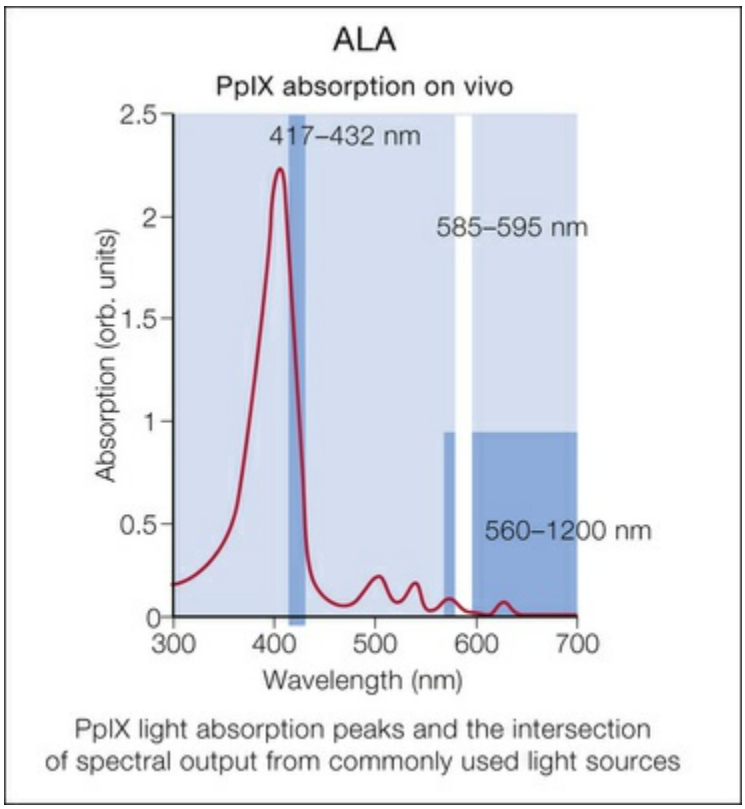


FIGURE 5.1 Protoporphyrin IX absorption: due to the multiple absorption peaks of protoporphyrin IX, multiple lasers and light sources can be used to augment the effects following application of porphyrin precursors to the skin.

Nonablative skin rejuvenation is commonly used to reverse photoaging in the dermis. This damage is directly correlated with the patient's age and extent of ultraviolet (UV) exposure. Ultraviolet B (UVB) light alters nucleic acids as it interacts with epidermal keratinocytes, inducing cellular atypia. Over time, longer-wavelength ultraviolet A (UVA) light causes increases in oxygen radical formation, inducing alterations in the normal homeostasis of vessel formation, apoptosis, pigment generation by melanocytes, immune cell dysregulation, cytokine dysregulation, alteration of dermal matrix composition, and disruption in the transcription, translation, and replication of the cellular genetic code. Histologic changes that accompany the clinical findings of photoaging include an atrophic epidermis, loss of the rete pattern, elastic fiber clumping in the papillary dermis, haphazard and reduced collagen production, and increased vasculature. These UV-induced changes correlate with the

clinical appearance of photoaged skin, including skin laxity, atrophy and fragility, increased rhytid formation, telangiectasia, and alteration in the overall color, texture, and consistency of the skin. Thus the goal of rejuvenation is to replace damaged epidermal and dermal constituents with more robust, newly created ones. Physicians attempt to alter the quality of the keratinocytes and the pigment production of melanocytes, two key components of epidermal photodamage. Dermal photodamage rejuvenation typically has concentrated on improving the function and durability of fibroblasts. Studies have shown an increase in antioxidant capacity and collagen synthesis after millisecond and nanosecond 532-nm and 1064-nm laser irradiation in fibroblast cell cultures.

Richard Glogau, MD, developed a classification scale to chart the progression of clinical photoaging (Table 5.1). One can follow a patient from an early age, with relatively strong homogeneity of skin coloration and minimal wrinkles, to a more aged patient, with wrinkles at rest and a more heterogeneous skin coloration.

Table 5.1

Glogau photoaging classification

Grade	Classification	Typical age	Description	Skin characteristics
I	Mild	20s or 30s	No wrinkles	Early photoaging: mild pigmentary change, no keratoses, minimal wrinkles, minimal or no makeup
II	Moderate	30s or 40s	Wrinkles in motion	Early to moderate photoaging: early solar lentigines, keratoses palpable but not visible, parallel smile lines begin to appear, wears some foundation
III	Advanced	50s	Wrinkles at rest	Advanced photoaging: obvious discolorations, visible telangiectasias, visible keratoses, wears heavier foundation always
IV	Severe	60s and older	Only wrinkles	Severe photoaging: yellow-gray skin color, prior skin malignancies, wrinkles throughout—no normal skin, makeup "cakes and cracks"

As one would expect, treating a Glogau grade I patient with current nonablative modalities will achieve a higher percentage of photoaging correction versus a more severely photodamaged patient. Although ablative skin rejuvenation may achieve superior restoration of normal skin structures, especially for the Glogau grade III or IV patient (see Table 5.1), the downtime and potential risks are prohibitive for many patients. As nonablative technologies evolve, restoration of young, healthy skin with diminished risks and negligible recovery times is increasingly possible. The remainder of this chapter will focus on patient selection for nonablative skin rejuvenation and discussion of the different devices.

Patient selection

Patient selection for nonablative skin rejuvenation begins with an assessment of the degree and type of photoaging (see Table 5.1). The ideal patient is Glogau grade II or III with mild-to-moderate photodamage. Nonablative therapies initiate new collagen formation (collagen I and collagen III) and might be

appropriate in a Glogau grade I patient to prevent photodamage progression. Alternatively, a patient and/or a physician expecting dramatic change following a nonablative rejuvenation procedure in a Glogau grade IV patient may be disappointed.

Sadick divides patients in a different manner, in which cosmetic deficiencies are based on the histologic location of solar damage. His selection process takes into account epidermal (type I) damage (Fig. 5.2) and dermal/subcutaneous (type II) damage (Fig. 5.3), and consequently treatment is tailored to selectively treat the damage.

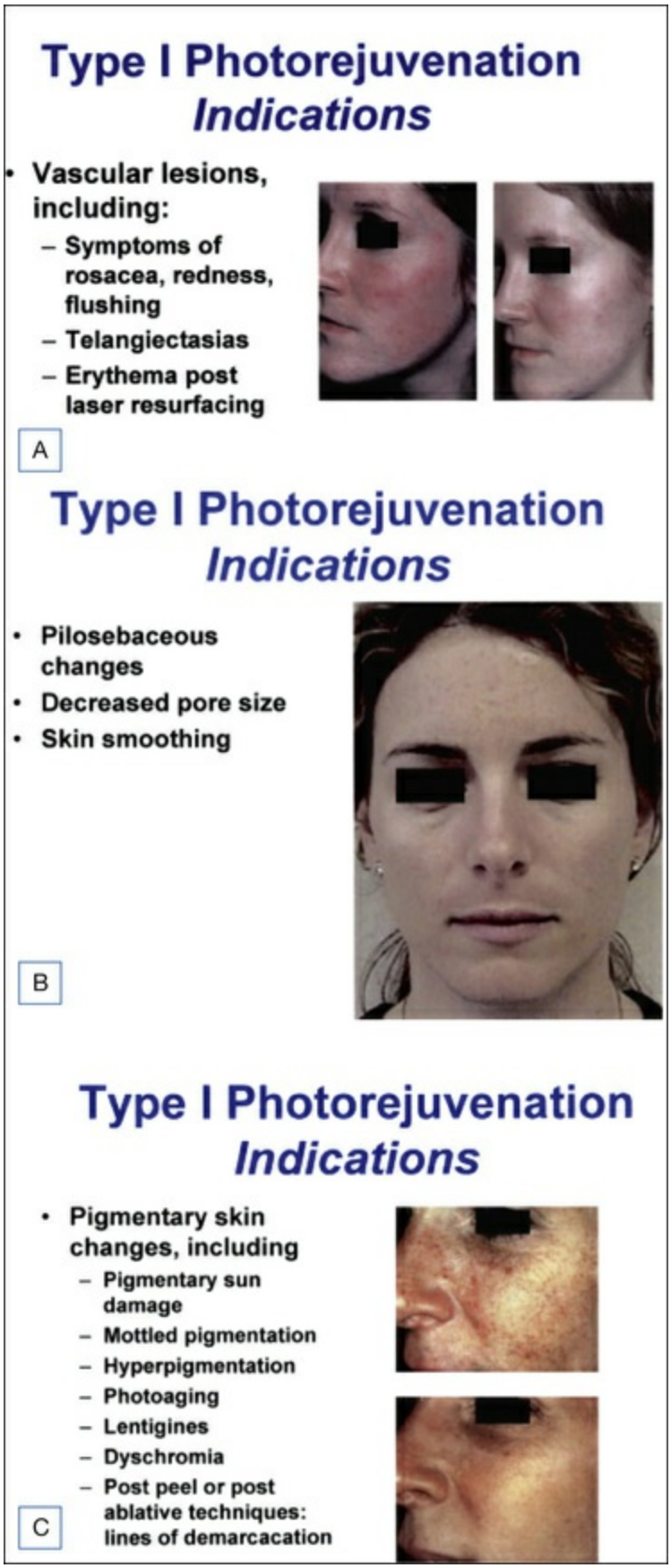


FIGURE 5.2 **A** to **C,** Type I photoaging indications. Republished with permission from Sadick NS. Update on non-ablative light therapy for rejuvenation: a review. *Lasers Surg Med.* 2003;32:120–128.



FIGURE 5.3 Type II photoaging indications. Republished with permission from Sadick NS. Update on non-ablative light therapy for rejuvenation: a review. *Lasers Surg Med*. 2003;32:120–128.

Another important factor in patient selection is the patient's Fitzpatrick skin type. Fitzpatrick IV, V, and VI skin types may not be optimal candidates for particular nonablative rejuvenation modalities that selectively heat melanin. The most common adverse result of nonablative rejuvenation in darker skin patients is hyperpigmentation, a condition that usually resolves after 4 to 8 weeks (but can persist longer in some circumstances) with appropriate application of suppressors of melanin synthesis. Mid-infrared lasers, which minimize direct melanin targeting, can be used in patients with darker skin types. However, higher fluences in these patients may result in thermal damage and bulk heating, which can also result in dyspigmentation. Noncryogen cooling devices can minimize bulk heating, whereas cooling devices that use cryogen spray, particularly when deployed over 80 ms, may induce pigmentary alterations similar to liquid nitrogen. See Chapter 10 for a detailed discussion of laser and non-laser light sources for the treatment of darker skin types.

Beyond skin type and amount of photodamage, there are some patients who might be excluded from nonablative lasers and light sources based on medical criteria (Box 5.2). Oral retinoid use, recent rejuvenation procedures, infection, and active dermatitis are reasons to consider deferring a nonablative rejuvenation procedure. Most likely oral retinoids will not affect outcomes, but no controlled study has investigated their effect on nonablative skin resurfacing. Some texts advocate waiting a period of 6 to 12 months, most likely representing an extrapolation from ablative resurfacing wait times. Several cutaneous laser experts have used nonablative devices 1 month following retinoid use without adverse outcomes.

Box 5.2

Relative contraindications for nonablative resurfacing

- Active dermatitis (i.e., acne, autoimmune disease)
- Active infection (i.e., herpes, impetigo)
- History of keloid or hypertrophic scar formation
- History of koebnerizing dermatitis (i.e., psoriasis, vitiligo)
- History of photoinduced dermatitis (i.e., polymorphous light eruption, lupus)
- History of oral retinoid use in the past 1 month
- Recent ablative resurfacing procedure
- Recent medium or deep chemical peel
- Recent surgery or treatment area requiring undermining

Physicians must also consider the wavelength of the device. For example, devices that use visible light (i.e., LED devices) may exacerbate a phototoxicity or photosensitivity or a systemic condition that is photosensitive, such as cutaneous lupus (although in a recent study only 7% of SLE (systemic lupus erythematosis) patients reacted to visible light) (Fig. 5.4). In contrast, some lasers may confer a protective quality. There is increasing evidence that IPL, for example, can activate fibroblasts, as well as confer protection from future UV-induced skin damage.



FIGURE 5.4 Severe photosensitivity reaction following photodynamic therapy (PDT). The patient is shown 6 days after PDT. Reaction resolved after 3 weeks.

Fillers and neurotoxins most likely are not affected by nonablative modalities and can be administered during the same session. However, nonablative resurfacing should be performed last. This order will minimize the risk of neurotoxin diffusion, which should cease by 1 hour after the injection, and will reduce the possibility of edema obscuring endpoints in optimal filler placement.

Visible light and near-infrared/vascular lasers (Table 5.2)

Visible light and near-infrared lasers are commonly used to treat vascular and pigmented lesions. Treatment of lesions with visible light lasers can achieve histologic correction of dyspigmentation, overall skin texture, dermal matrix abnormalities, and solar elastosis. Clinical improvement of solar lentigines, scars, including keloids and hypertrophic scars, and photoaging have all been observed. Orringer et al. have reported increases in type I procollagen messenger RNA and subsequent dermal matrix remodeling following one treatment with a flashlamp-pumped pulsed dye laser (PDL). Whether this is secondary to thermal alterations of cellular milieu or to vascular-injury-induced cytokines, the result is dermal remodeling, reversal of photoaging, and partial rhytid correction.

Table 5.2

Commonly used visible light/vascular lasers in nonablative resurfacing*

Wavelength (nm)	Laser type	Energy	Pulse duration (ms)
532	Flash/arc lamp-pumped KTP	Up to 950 J/cm^2	5–100
532	Diode-pumped KTP	0.1–5 W	5–1000
585–595	Pulsed dye	Up to 40 J/cm^2	0.45–40, 350
755	Alexandrite	1–50 J/cm^2	0.5–300
808	Diode	Up to 170 J/cm^2	Up to 1000
940	Diode	Up to 900 J/cm^2	5–625
532/1064	Q-switched Nd:YAG	Up to 16 J/cm^2/Up to 37 J/cm^2	5–20
1064	Nd:YAG	Up to 990 J/cm^2, 120 J	0.1–300

*This table represents a wide range of available lasers with some utility in nonablative resurfacing. As each device has unique properties and settings, please refer to each specific device's manual for exact information to optimize patient treatment.

KTP, Potassium titanyl phosphate; *Nd:YAG*, neodymium:yttrium-aluminum-garnet.

The first laser designed de novo to exploit the principle of selective photothermolysis was the PDL. The laser was optimized to treat port-wine stains. As the understanding of treatment of vascular lesions has progressed, so has the configuration of the PDL, in both composition of the dye (rhodamine) and wavelength. In its approximate 35-year existence, the PDL has moved beyond its original 577-nm wavelength, which corresponds to a hemoglobin absorption peak, and its early 0.3- to 0.45-ms pulse duration. Currently, commercially available PDLs emit wavelengths between 585 nm and 595 nm, which penetrate deeper into the dermis and into deeper vessels. Newer PDLs have greater pulse duration ranges, most generating pulse trains of up to 40 ms, which avoid intravascular thrombosis in very small vessels and subsequent purpura. Other than direct vascular heating and a resulting increase in dermal temperature, vessel targeting can also create an inflammatory cascade that results in new collagen formation. Bjerring showed a 148% increase in type II collagen 2 weeks after low-fluence PDL treatment and only a 32% increase with IPL; however, the authors conceded that the IPL settings (4 to 7 J/cm^2) were lower than those used in conventional application for red-brown dyschromias.

Other wavelengths that target hemoglobin in blood vessels have been shown to rejuvenate skin. The long-pulsed 755-nm alexandrite laser (Case Study 1), the 810-nm diode, and the 1064-nm neodymium:yttrium-aluminum-garnet (Nd:YAG) lasers are used for deeper and larger-caliber vessels. The subsequent "coincidental" dermal remodeling correlates with the depth of penetration of each respective laser. Weng et al. have demonstrated that collagen synthesis by fibroblasts and antioxidant enzymes were significantly increased following irradiation with the 532-nm, 1064-nm Q-switched Nd:YAG and 1064-nm long-pulse Nd:YAG lasers. The 1064-nm Nd:YAG laser induces deeper remodeling than the 532-nm laser due to its lower degree of dermal scattering and chromophore absorption at 1064 nm. Thus some physicians use multiple lasers, such as the 532-nm laser to treat dyschromia and telangiectasia, followed by a pass with the 1064-nm laser, to obtain some deeper remodeling in the same

treatment session.

RF devices that deeply heat in a broad pattern over the surface are typically applied in a moving fashion, where the operator guides the handpiece over the skin back and forth in a rotating manner (Fig. 5.5). The surface temperature (T) tends to be optimal around 40°C to 42°C; greater Ts are too painful and/or might cause surface damage, and lower Ts seem to be ineffective. The real subsurface T for these devices has typically only been determined in models. For purposes of this chapter, we will confine discussion to RF needle and bipolar devices. The monopolar and ultrasound devices, which achieve deeper heating are discussed in Chapter 9. Sadick and Makino examined the electrothermal reactions in skin, using models with both bipolar configurations, and found that T elevations in the skin extended to a depth that represented half the distance between the electrodes, where the energy is "forced "between the electrodes (Fig. 5.6). Many newer systems have adapted impedance matching that adjusts the power in relation to tissue resistance for optimal energy delivery into the skin. Most devices that use a motion technique rely on creating a temperature gradient where the surface is presumably cooler than the superficial dermis. As the maximum electrical field is at the electrode edges, there are two mechanisms to increase the dermal to epidermal damage ratio. One method is to cool the active electrodes. Cooling increases the surface impedance and protects the epidermis. In addition, the epidermis, exposed to the ambient temperature, should cool at the surface faster than the deeper dermis. The surface T, even at 42°C, should allow for T elevations to 45°C to 50°C at 1 to 2 mm deep in the dermis because the dermis will be slower to cool after the long time application of the RF tip.

Pearl 1

Combination treatment results in improved treatment results. The authors note improved outcomes with patients treated with a combination using the 532-nm and 1064-nm lasers during the same treatment session. By using combination treatment, multiple chromophores can be targeted, with the 532-nm laser treating lentigines and telangiectasias, whereas the 1064-nm laser, by nature of its absorption spectrum, augments the rhytid correction of the 532-nm laser. In addition, a long-pulsed visible light technology (IPL, PDL, or large spot [10 to 12 mm] potassium titanyl phosphate [KTP] device) can be applied first to reduce vascular dyschromias and darker lentigines, followed by treatment in the same session with a Q-switched laser to address so-called low-contrast pigmented lesions.

Case Study 1

A white female in her early 60s presents for total facial rejuvenation with request to focus on lentigenes, telangiectasias, and overall facial rejuvenation (Fig. 5.7A). The long-pulsed alexandrite 755-nm laser was used at a fluence of 36 J/cm^2 using an 8-mm spot size and a 3-ms pulse duration to treat the patient's forehead, cheeks, nose, and chin. At 6 weeks following her treatment,

significant improvement in hyperpigmented macules, telangiectasias, and an overall more youthful appearance is appreciated (see Fig. 5.7B).



FIGURE 5.5 Note electrode placement over neck, in this configuration, the operator moves the electrode over the neck in a circular fashion until a surface temperature of approximately 40°C to 42°C is achieved over 5 to 10 minutes per area (Fractora Forma, Inmode Inc., Irvine, California).

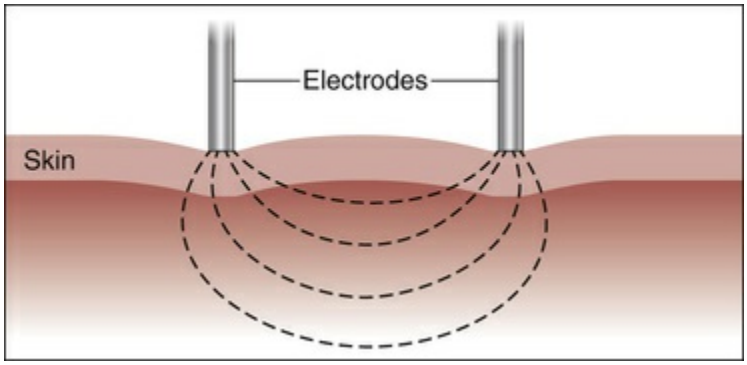


FIGURE 5.6 Note schematic of bipolar electrode against the skin and electric field geometry between the electrodes. The current flows to a maximal depth of approximately half the distance between the electrodes. From Sadick, NS, Makino, Y. Selective electro-thermolysis in aesthetic medicine: a review. *Lasers Surg Med.* 2004;34(2):91–97.

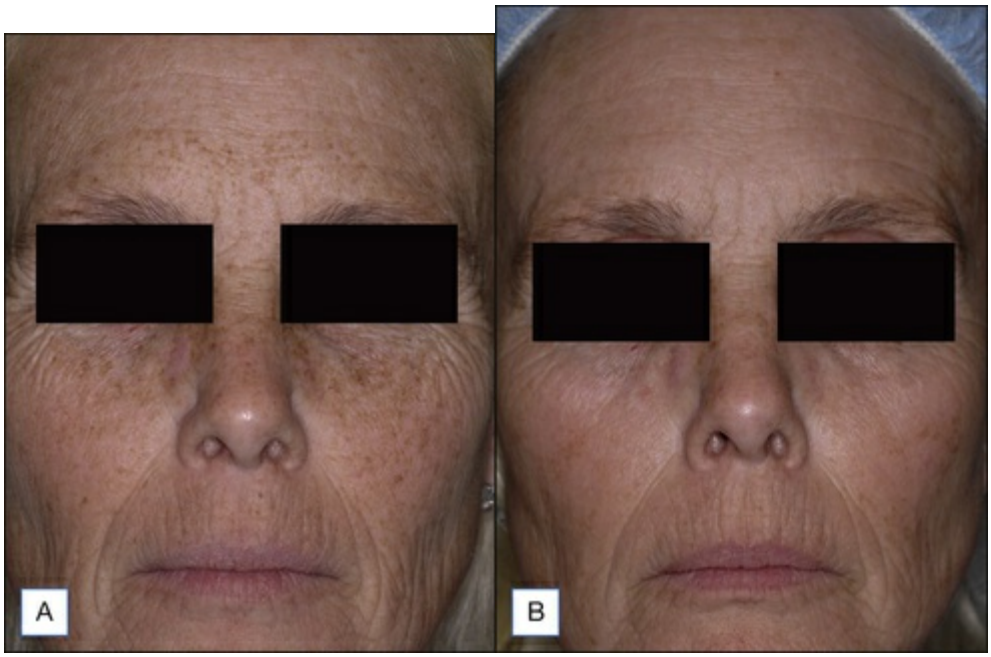


FIGURE 5.7 Patient treated with long-pulsed alexandrite laser for photorejuvenation: (**A**) pretreatment and (**B**) posttreatment.

Near-infrared lasers have been used in a motion technique for skin rejuvenation. In one scenario, a 1064-nm laser equipped with a 5- or 7-mm spot size is deployed in a rapid back-and-forth fashion at 5 Hz and 12 to 15 J/cm^2. The device is moved from region to region based on either the surface temperature or when the heat becomes too uncomfortable to the unanesthetized patient. Typically one achieves a surface temperature of approximately 39°C to 42°C and then moves to an adjacent region. The lack of anesthetic is imperative in this approach because excessive pain must be reported by the patient and should alert the operator to move and prevent epidermal injury. The procedure (Laser Genesis, Cutera, Brisbane, California) is easy to perform and results in only mild erythema postoperatively. In a study of 50 Asian patients evaluated by photography and biopsies, improvement in wrinkles, pore size, and elastin production were noted. No epidermal cooling was required. Another tool for NAR is the Q-switched Nd:YAG laser. Used in a motion technique at 5 to 10 Hz and 2 to 4 J/cm^2, the laser is applied with a 4- to 6-mm spot and multiple passes. End points are mild erythema, and the laser can be applied in multiple sessions 2 to 4 weeks apart. Often a modest reduction in fine lines, scars, and dyschromia is observed.

Other devices that heat the mid-dermis include halogen lamps and xenon flashlamps. The output of the former ranges from 1100 to 1300 nm, and the output of the latter ranges from approximately 600 to 1200 nm. Like their laser near-infrared counterparts, the effect is gentle heating of the mid-dermis and upper hypodermis. These devices straddle the applications of skin tightening and skin rejuvenation, which is a somewhat arbitrary distinction in which tightening has been defined as overall skin contour enhancement. In contrast, these devices heat superficially enough that more general and ambiguous changes are observed. In one side-by-side study, a halogen lamp device

improved skin laxity in 41% of patients. As in most of these types of studies, in which gentle sustained heating is applied, the subjective improvement rates exceed objective outcome measures of improvement.

Adverse effects associated with all vascular lasers range from dyschromia, purpura, and blistering to scarring. Epidermal cooling techniques decrease surface heating and minimize pigmentary alteration. This addition is imperative in patients with Fitzpatrick IV to VI type skin treated with visible light lasers. Patients with a recent tan may also warrant a test spot. Epidermal cooling may be used prior to or following laser treatment by application of multiple different cooling devices, like a cold aluminum "roller," ice packs, chilled sapphire windows, other contact cooling mechanisms, refrigerated air cooling or cryogen spray cooling. Purpura, blistering, and scarring can be avoided by knowledge and appropriate alteration of the fluence, spot size, and pulse duration when treating different skin types.

Pearl 2

When treating with modalities that use contact cooling mechanisms, it is important to minimize the condensation that can sometimes accumulate, which occurs most commonly with sapphire or glass windows. This condensation attenuates the laser beam and decreases the efficacy of the treatment.

Mid-infrared lasers (Table 5.3)

Clinical and histologic evidence of nonablative, nonfractional skin rejuvenation has been observed after use of mid-infrared lasers. The 1320-nm Nd:YAG laser was the first commonly used nonablative mid-infrared laser to rejuvenate skin. When combined with surface cooling, collagen remodeling is achieved without epidermal damage. With water as the chromophore, the nonspecific dermal thermal injury creates edema, vascular changes, and alterations in fibroblast assembly of dermal matrix constituents. The healing sequence can result in mild correction of rhytides. The 1450-nm diode laser has been used for nonablative rejuvenation in the same way as the 1320-nm Nd:YAG.

Table 5.3

Commonly used mid-infrared lasers/devices in nonablative resurfacing*

Wavelength (nm)	Laser type	Energy	Pulse duration (ms)	Spot sizes (mm)	Cooling
1319	Nd:YAG	Up to 30 J/cm^2	5–200	6, 30 × 30	Integrated cooling
1320	Nd:YAG	5–40 J/cm^2	30–200	6, 10	Integrated contact cooling, integrated cryogen spray
1450	Diode	Up to 25 J/cm^2	210, 250	4–6	Integrated dynamic cooling device, integrated cryogen

					spray
1540	Erbium:glass	10–30 J/cm²	3–100	4	Sapphire lens
515–1200	IPL	Up to 70 J/cm²	1–500 (single mode) 2.2–12.5 (pulsed mode)	10, 12, 15, 15 × 8, 15 ×10, 20 × 10, 20 × 30, 30 × 10, 34 × 8, 35 × 15, 34 × 18, 50 × 25, 50 × 10, 46 × 18, 46 × 10	Chilled tip contact cooling

*This table represents a wide range of available lasers with some utility in nonablative resurfacing. Because each device has unique properties and settings, please refer to each specific device's manual for exact information to optimize patient treatment.

IPL, Intense pulsed light; *Nd:YAG*, neodymium:yttrium-aluminum-garnet.

The 1540-nm erbium:glass laser similarly induces tissue water heating, thermal injury, and neocollagenesis. This laser penetrates to a depth intermediate between 1320 nm (deepest) and 1450 nm (shallowest) among this wavelength range. In planning strategies with all the mid-infrared wavelengths, the depth of penetration should coincide with the depth of solar elastosis.

Each of the nonfractional mid-infrared lasers uses a cooling system to minimize epidermal damage and pigmentary alteration. One 1320-nm Nd:YAG laser uses either a pre- or post-laser spray, whereas another uses a contact chiller plate and scanner. The 1450-nm diode laser applies cryogen before, during, and after the laser pulse. These combinations of longer wavelengths and surface cooling make these lasers favorable for Fitzpatrick IV, V, and VI skin types. However, particularly in the case of the 1450-nm system, in which the total spray time is delivered over a long period (up to 220 ms), there is a risk of cryoinjury. The shorter spray times with the 1320-nm laser and the 5°C sapphire lens incorporated into the 1540-nm erbium:glass laser have not been associated with cryoinjury.

The side effect profile of each of these lasers has a direct correlation with the fluences applied in the treatment of rhytides or acne scars. The efficacy of these devices has proven modest in most cases, and providers must be cautious to avoid pigmentary changes and the rare case of scarring, which is typically secondary to treatment using a fluence that is too high.

Pearl 3

Caution must be used when using higher fluences in smaller cosmetic units (i.e., upper lip). High fluences may increase bulk heating and increase risk for hyperpigmentation or scarring.

Intense pulsed light

IPL devices emit a broad spectrum of wavelengths between 400 and 1200 nm to target multiple structures. These devices, although not emitting monochromatic, collimated, or coherent light, still use selective photothermolysis. IPL targets specific chromophores by using available filters to select certain wavelengths within the 400- to 1200-nm range. Shorter

wavelengths can be used to treat lighter-skinned patients, or the spectrum can be "red shifted" through filters or through electronic modulation to minimize melanin absorption in darker-skinned patients. Peaks of hemoglobin absorption can be selectively used to target vascular structures. Finally, for purposes of nonablative skin rejuvenation, dermal water can be targeted to induce photothermal initiation of neocollagenesis.

The utility and potential risks of the IPL are associated with its diversity. An IPL can be configured to treat the most clinically relevant chromophores (water, melanin, hemoglobin) and thereby multiple dermatologic conditions. There are many available IPL units with a wide array of designs and treatment parameters. Newer systems have improved by adding sophisticated graphical user interfaces with application-specific, user-friendly preprogrammed settings. However, one should become comfortable with one or two IPL systems because each has different interfaces, wavelength spectrums, filters, power outputs, pulse profiles, cooling systems, and spot sizes. Some of the parameter sets do not allow different IPL systems to be compared easily. For example, there are some IPL devices that calculate their fluences based partly on theoretical modeling and photon recycling, whereas others determine fluence based solely on an actual output at the sapphire or quartz window on the handpiece tip. Thus moving from one IPL device to another does not mean that you will achieve the same outcome with the same settings on the display panel. A spectrophotometer (color meter) is provided with one new IPL (Icon, Cynosure, Westford, Massachusetts). The meter transmits the patient pigment level directly to the IPL via Bluetooth technology. The graphic user interface then shows suggested test spot settings for that particular skin region.

Pearl 4

Good contact between the handpiece and the skin along with taut pressure may maximize the depth of laser light penetration, evenly treat the skin within the spot size, and will decrease the risk of postinflammatory hyperpigmentation. When using IPL devices to treat the face, this becomes very important, especially in darker-pigmented skin, because the face is full of many crevices and contours and most IPL devices use a rectangular handpiece, which makes good contact difficult in the perinasal and periocular regions. Some IPLs make available smaller dedicated spot-sized handpieces (6 to 12 mm), whereas others use snap-on adaptors that truncate the light footprint and allow for easier deployment over irregular skin surfaces.

Finally, although the utility of IPL devices allows for treatment of a wide variety of conditions, the addition of RF has been used to supplement and improve outcomes with the use of IPL devices (Elos, Syneron-Candela). The technology is known as electro-optical synergy (ELOS). Bipolar RF exhibits a preference for warmer tissue. This technology takes this property into consideration by using the IPL system to preheat the target chromophore and then using the RF technology to further heat the tissue target. Contact cooling

helps to avoid epidermal damage. This synergistic technology has shown its efficacy in treatment of photoaging and in helping to reduce wrinkles, lentigines, and telangiectasias. More recently, it has been added to the long-pulse alexandrite and PDLs in clinical trials. One of the goals of ELOS applications is to increase the ratio of dermal to epidermal heating by decreasing the optical fluence.

Light-emitting diodes (applied in the absence of a photosensitizer such as aminolevulinic acid)

Light-emitting diodes (LEDs) for photoaging consist of a panel(s) of numerous small lamps that emit high-intensity light. Some companies have miniaturized these devices to handheld units that are used at home, whereas most professionals are using panels that can treat the entire face in one treatment session. One advantage of LED devices is that they are well tolerated by patients. With no pain, large surface areas of skin can be treated simultaneously.

Typically LED devices emit a range of wavelengths. These devices are available in various wavelengths from blue to infrared. Depending on the wavelength and treatment parameters, LEDs emit milliwatt light in a small range around a peak wavelength. Thus, for example, if one were to select an LED with a dominant wavelength of 500 nm, the device will likely emit light from approximately 480 to 520 nm. However, more advanced LEDs with very tight temperature controls are now available with much smaller bandwidths and less wavelength "drift."

The interaction of LED devices with the skin is unclear, although most believe that photomodulation of cell receptors, cell organelles, or existing protein products is partially responsible. Unlike many of the devices discussed previously, nonthermal interactions with the extracellular matrix and fibroblasts remodel existing collagen, increase collagen production by fibroblasts, inhibit collagenase activity, and result in rhytid reduction.

One early LED system was the Gentle Waves device (Light BioScience, LLC, Virginia Beach, Virginia). The system generates 588-nm yellow light pulses with an on-time of 250 ms and off-times of 10 ms for a total of 100 pulses, resulting in a total light dose of 0.1 J/cm^2. Although some trials showed significant improvement in pore size, skin tone, and texture, the most comprehensive controlled clinical trial showed no significant skin changes in objective outcomes after a series of treatments. Boulos found that there was a strong placebo effect with the 588-nm Gentle Waves system and that little objective improvement was observed by blinded raters. Despite the subjective improvement in two trials, objective improvement in blinded studies is unproven.

In a study of 633- and 830-nm LED biostimulation, two treatments per week

over 4 weeks showed increases in collagen production and mild wrinkle improvement. In a study using a reconstructed skin substitute irradiated with 633-nm LED panels, increases in collagen production were also observed. In addition, in the clinical arm of the study, patients receiving treatment three times a week for 4 weeks (12 treatments) were found to get mild-to-moderate wrinkle improvement compared with sham treatment.

Photodynamic therapy

Since 1999, photosensitizing agents have enjoyed an increasing role in medical and cosmetic dermatology. Twenty percent 5-aminolevulinic acid (5-ALA, a "prodrug") is absorbed by rapidly proliferating epidermal and dermal cells and converted into photoreactive products of the hemoglobin pathway, most notably protoporphyrin IX (see Fig. 5.1). Protoporphyrin IX is subsequently activated by certain wavelengths of light, as highlighted by the absorption peaks in Fig. 5.1, resulting in singlet oxygen production and resultant cellular destruction.

Many light sources have been used for PDT (Box 5.3). This variety is possible owing to multiple absorption peaks by protoporphyrin IX. The largest peaks are at 417, 540, 570, and 630 nm. The PDL, IPL, and LED devices have all been used to activate protoporphyrin IX. There are many variables that affect the immediate PDT response, among them the ALA incubation time, pre-ALA skin preparation regimen, degree of skin photodamage, anatomic region, light dose, wavelength range, skin temperature, and power density. Overall, lower power densities (i.e., continuous wave light sources) create more singlet oxygen than pulsed light. In addition, we have found that applying anesthetic creams simultaneously with the ALA solution can accelerate ALA absorption and thereby accelerate protoporphyrin formation, leading to a much more robust response.

Pearl 5

Microdermabrasion, chemical peels, acetone, alcohol, retinoids, and thorough cleansing of the treatment area have all been advocated for making the stratum corneum more uniform, increasing the likelihood that the PDT will penetrate deeper and more evenly.

Many studies have shown the improvement of actinic keratoses and acne with PDT. Some studies have shown evidence of increased collagen formation. Gold et al. have reported improvement in crow's feet, skin texture, mottled hyperpigmentation, telangiectasias, and actinic keratoses with the addition of 5-ALA prior to IPL treatment (Case Study 2).

Case Study 2

A 57-year-old white male presents for evaluation and treatment of overall actinic damage, including actinic keratoses and lentigines on his cheeks (Fig.

5.8A). Treatment was initiated by the application of Levulan (DUSA Pharmaceuticals, Inc.), a 2-h incubation period, and blue light for 5 min; 5% lidocaine cream was placed on the treated areas for the last 30 min of the patient's ALA incubation, which has been shown to enhance ALA absorption and PDT effect. Finally, the 532-nm long-pulsed green laser (Gemini, Cutera, Brisbane, California) was used with contact cooling at a fluence of 7 J/cm^2 and 18-ms pulse duration using a 10-mm spot size to treat the entire cheek and nose area. Two months after treatment, the patient's actinic damage was significantly improved (see Fig. 5.8B).

Box 5.3

Lasers and light sources used with aminolevulinic acid-photodynamic therapy

1. IPL Quantum SR* (Lumenis Ltd., Yokneam, Israel)

a. 560 nm filter

b. Double pulse (2.4/4.0 ms with 10 ms delay)

c. Single pass with no overlap

d. 25–35 J/cm^2

2. Lumenis One* (Lumenis Ltd., Yokneam, Israel)

a. 560 nm filter

b. Double pulse (4.0/4/0 ms with 20 ms delay)

c. Single pass with no overlap

d. 15–25 J/cm^2

3. VascuLight SR* (Lumenis Ltd., Yokneam, Israel)

a. 560 nm filter

b. Double pulse (3.0/6.0 ms with 10 ms delay)

c. Single pass with no overlap

d. 30–35 J/cm^2

4. Icon Pulsed Light System* (Cynosure, Westford, Massachusetts)

a. 20 ms

b. 19–30 J/cm^2

c. Single pass with no overlap

5. Photogenica V Star* (Cynosure Inc., Chelmsford, Massachusetts)

a. 585–595 nm wavelength PDL

b. 10 mm spot size

c. 40 ms pulse width

d. 7.5 J/cm^2

e. Two passes with 50% overlap

6. V Beam (Candela Corp., Wayland, Massachusetts)

a. 595 nm PDL

b. 10 mm spot size

c. 6 ms pulse width

d. 7.5 J/cm^2

e. Two passes with 50% overlap

7. ClearLight* (Lumenis Ltd., Yokneam, Israel)

a. 405–420 nm blue light

b. 8–10 min under light

8. BluU* (DUSA Pharmaceuticals, Inc., Wilmington, Massachusetts)

a. 417 ± 5 nm blue light

b. 8–15 min under light

9. SkinStation* (Radiancy, Orangeburg, New York)

a. 500–1200 nm pulsed light

b. Two passes

c. 45 J/cm^2

. Aurora (Syneron Medical Ltd., Irvine, California)

a. 580–980 nm

b. Optical energy of 16–22 J/cm^2

c. Single pass

. Sciton BBL* (Sciton Inc., Palo Alto, California)

a. 560 nm BBL filter

b. 14 J/cm^2

c. 12 ms

d. Single pass

The following lasers and light sources are currently being used by the author for ALA-PDT treatments for AKs (other devices listed above are also able to be used) with similar parameters as listed above:

1. Icon IPL (Cynosure, Westford, Massachusetts)

2. Omnilux Blu and Red (PhotoMedex, Orangeburg, New York)

3. Sciton BBL (Sciton, Palo Alto, California)

4. Ellipse Nordlys (Ellipse medical, Hørsholm, Denmark)

5. Excel V (532 nm, Cutera, Brisbane, California)

6. Lumecca (Inmode, Irvine, California)

ALA-PDT, Aminolevulinic acid-photodynamic therapy; *PDL,* pulsed dye laser.

*Device used by author: other settings from colleagues.

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FIGURE 5.8 Treatment of photoaging with aminolevulinic acid (ALA)/Gemini 532-nm, long-pulsed green laser: (**A**) pretreatment and (**B**) posttreatment.

Radiofrequency microneedling

There are now many RF needle and/or small electrode array devices on the US market. Depths of penetration range from approximately 0.6 to 3.5 mm (Fig. 5.9). Some of the devices deliver energy just along the surface, whereas others are depth-adjustable and can reach the dermal–subcutaneous junction. Both insulated and noninsulated designs are available. The goal is to deliver focal injuries to the skin in a pattern of coagulation zones strategically placed to reverse the presenting pathology. One to three passes are typically made, depending on the specific technology. Cross-sectional densities range from 5% to 20%. Often one will hear that RF devices are "color blind." For the surface-heating motion devices this is true; however, for the needle devices, if one applies the injuries very superficially, postinflammatory hyperpigmentation is possible. The loss of elastic tissue in scars contributes to cosmetic and functional deficits and a primary reason for skin aging is a loss of elasticity; RF needles, more than any other technology to date, appears to enhance elastogenesis (Fig. 5.10). A paper by Ozog et al. showed no effect on elastic tissue staining after fractional CO_2 laser. In contrast, Hantash showed that after RF needling, neoelastogenesis was observed.

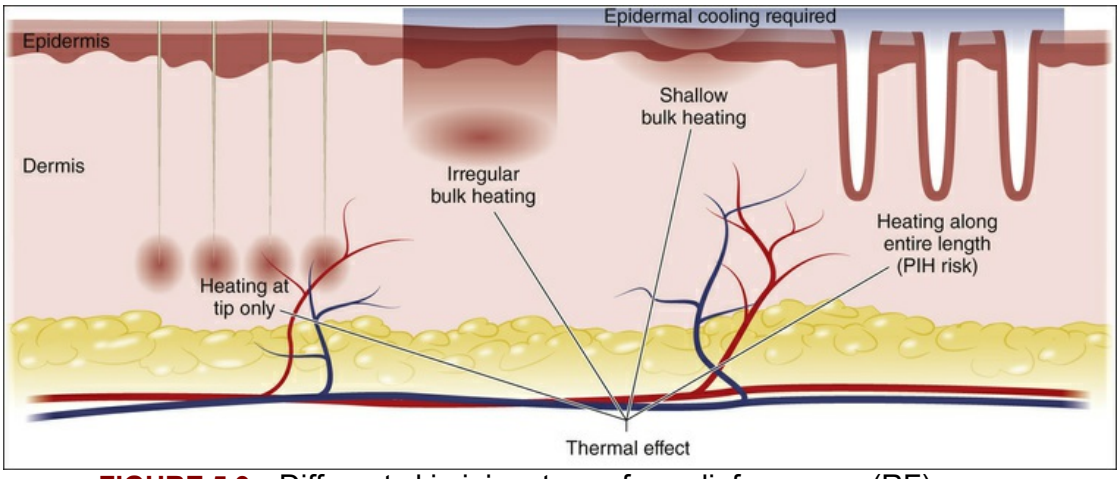


FIGURE 5.9 Different skin injury types for radiofrequency (RF) configurations (left to right, insulated needles, large monopolar electrode, bipolar electrodes, and uninsulated needles).



FIGURE 5.10 (**A**) Before and (**B**) after one treatment with radiofrequency (RF) needle array.

Radiofrequency motion technique large electrode heating devices

In the case of the motion techniques, one moves the handpiece usually in a circular or back-and-forth fashion over areas ranging from approximately 5 × 10 cm^2 (see Fig. 5.5). For example, a typical region might be a cheek where for 5 to 10 minutes the device achieves a surface temperature of 39°C to 42°C. These temperatures are typically monitored externally by a relatively inexpensive temperature monitor (Fig. 5.11) or by a built-in temperature sensor at the tip of the device. These procedures are carried out without topical anesthesia because feedback from the patient is very important in avoiding overheating of the skin. The intent here is to establish a relatively long time–temperature combination that presumably can initiate some modest neocollagenesis in the upper and mid dermis. These procedures are well tolerated and safe, but results are oftentimes modest and do not produce readily identifiable microscopic injuries on routine histology.



FIGURE 5.11 External temperature monitor aimed at skin during radiofrequency (RF) treatment.

Overview of treatment strategy

Patient selection is important to obtain the best expectation–outcome match. Patients may present for treatment of wrinkles and not the other characteristics of photoaging, even though telangiectasia or lentigines may be present. The modality of treatment is also important as each light device offers unique advantages. For example, if the patient presents with a concern of excessive telangiectasia, use of the 532-nm KTP, a PDL, or an IPL device may be warranted. If the goal is to obtain deeper dermal remodeling, one could consider longer-wavelength modalities, such as the mid-infrared devices or RF devices. Due to the widespread use and versatility of IPLs, many dermatologists are treating multiple photoaging characteristics simultaneously, including hyperpigmentation, telangiectasia, rhytides, and skin texture abnormalities. If the patient presents with actinic keratosis or sebaceous hyperplasia, PDT can be performed either at the same appointment or before or after visible pulsed light treatment for red and brown dyschromias. Often a patient presents with multiple telangiectasias and actinic keratoses. If one uses only a vascular laser or IPL, the actinic damage and the associated telangiectasias within the actinic keratoses will persist or relapse; accordingly, either pretreatment with 5% fluorouracil cream or PDT will enhance the total rejuvenation effect and decrease the likelihood of an incomplete response (Case Study 3).

Case Study 3

A 51-year-old white male presents with hyperpigmented patches along bilateral cheeks, as well as multiple actinic keratoses on his cheeks and forehead (Fig. 5.12A). Treatment was initiated by the application of Levulan (DUSA Pharmaceuticals, Inc.), a 2-h incubation period, and PDT illumination. He was subsequently treated with the V-Beam Perfecta (Syneron-Candela

Corporation USA, Irvine, California) using a 10-mm spot size, 8 J/cm^2, a 10-ms pulse duration, with 3 bars of cooling to bilateral cheeks. At 6-week follow-up, there was significant reduction in actinic keratoses, solar lentigines, and telangiectasias, as well as overall facial rejuvenation (see Fig. 5.12B).



FIGURE 5.12 Patient treated with combination therapy aminolevulinic acid (ALA)/photodynamic therapy (PDT) and PDL with marked improvement in actinic damage, lentigines, telangiectasias, and overall skin quality: (**A**) pretreatment and (**B**) posttreatment.

With all lasers or light modalities, preparation of the patient and the clinical setting are important. All required items (gauze, gel, eye protection, etc.) should be placed on an easily accessible Mayo stand. The treating handpiece should be cleaned according to the manufacturer's instructions and the device be

positioned so that no cords or fibers are under tension.

Many physicians advocate pretreatment use of a topical retinoid, not only to maximize medical photocorrection but also to reduce the risk of dyspigmentation following treatment. Just prior to the procedure, the patient's skin should be cleansed. Any residual debris, including oil, makeup, lotions, or topical anesthetics (if administered) may impede the delivery of light to the skin and can be removed with alcohol. This alcohol should be allowed to completely dry prior to treatment.

The physician should always obtain pretreatment photographs. The patient should be placed and draped in a position that allows full access to the treatment area. This is typically achieved by placing the patient in the supine position to treat such photodamaged areas as the face, neck, chest, and forearms. Appropriate goggles or eye shields (internal or external depending on the treatment area) are then applied to ensure proper ocular protection. It is helpful to inform the patient, even with appropriate eye protection, about the likelihood of seeing a flash of light during the procedure. Many patients become anxious regarding the dangers of lasers when they see a flash of light even when they have goggles or shields over their eyes. Informing them that they are adequately protected puts them at ease.

Conclusion

Nonablative rejuvenation remodels photodamaged dermal constituents without inducing an epidermal wound. Minimal recovery times make this approach appealing to physicians and patients alike. Reversal of dyschromias (pigment and vascular) are reasonably predictable. Unfortunately, at this point, in the eyes of many clinicians, objective clinical and histologic outcomes with nonablative technologies do not correlate with clinician expectations, with the exception of novel fractional lasers and visible light technologies that target pigmented and vascular lesions.

Check online videos (Video 5.1 - 5.4).

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6

Nonablative fractional laser rejuvenation

Jeffrey S. Dover



Summary and Key Features

- Nonablative fractional resurfacing is a safe and effective treatment that has become the cornerstone for facial rejuvenation and acne scarring.
- It is effective in treating a variety of conditions, including acne scarring, mild-to-moderate photoaging, and some forms of dyspigmentation.
- Nonablative fractional photothermolysis has minimal downtime with almost no restrictions on activity immediately following treatment.
- Common areas treated include the face, neck, chest, arms, and hands.
- All Fitzpatrick skin phototypes can be treated, provided settings are adjusted accordingly.
- The preoperative consultation is a vital component of the treatment regimen to ensure optimal outcomes.
- Erythema and edema are common sequelae after treatment and resolve within a few days
- Long-term complications are exceedingly rare.
- Technology in the field is changing rapidly, and the selection of equipment is based on individual preference.
- Home-based devices are a new frontier for fractional resurfacing, but results

are modest, and as a result these systems will not replace office-based lasers.

Introduction

Treatment approaches are constantly being developed and refined in the field of skin rejuvenation. Since its original introduction in 2004 fractional photothermolysis has provided rejuvenation treatment approaches that are both effective and safe. Introduced by Anderson and Manstein, fractional photothermolysis generates targeted microthermal zones (MTZs), columns of thermally denatured skin of controlled width and depth, in the dermis. Their original device using this technology induced columns of necrosis within the epidermis and dermis while leaving the stratum corneum histologically intact and without removing any of the skin and was thus termed nonablative fractional photothermolysis (NAFR).

One of the main advantages of NAFR is limited discomfort and the minimal recovery after the procedure. In contrast to conventional resurfacing devices, fractional photothermolysis treats only a fraction of the skin, allowing for rapid repair from undamaged areas. Although multiple treatment sessions are required to achieve the desired outcome, downtime is limited to an average of 3 days of redness and swelling, as opposed to an average of 7 to 10 days of an open wound after aggressive nonfractional ablative resurfacing. Combined with an excellent safety profile, NAFR has become the cornerstone of laser skin rejuvenation for the treatment of photoaging, acne scarring, and a variety of other clinical applications.

Pathophysiology

In fractional photothermolysis, a regular array of pixelated light energy creates focal areas of epidermal and dermal tissue damage or MTZ (Fig. 6.1). Since its inception, several different lasers have been developed to take advantage of this technologic advance. Each laser has parameters that can be modified to alter the density, depth, and size of the vertical columns of MTZs. The individual wounds created by FP are surrounded by healthy tissue, resulting in a much quicker healing process when compared with traditional ablative skin resurfacing. This targeted damage with MTZ is believed to stimulate neocollagenesis and collagen remodeling leading to the clinical improvements seen in scarring and photoaging. In the original study by Manstein et al. the histologic changes seen after NAFR were elegantly described. Immediately following treatment, lactate dehydrogenase (LDH) viability staining showed both epidermal and dermal cell necrosis within a sharply defined column correlating with the MTZ. There was continued loss of dermal cell viability 24 hours after treatment, but via a mechanism of keratinocyte migration the epidermal defect had been repaired. One week after treatment, individual MTZs were still evident by LDH staining, but after 3 months there was no histologic evidence of loss of cell viability. Water serves as the target

chromophore allowing for thermal damage to epidermal keratinocytes and collagen.

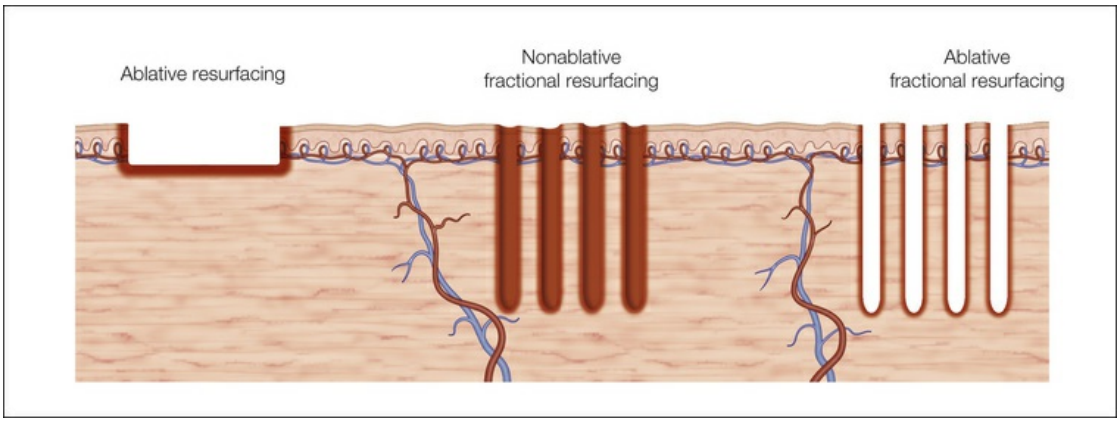


FIGURE 6.1 Diagram showing the differences between traditional ablative, nonablative fractional, and ablative fractional resurfacing. With the fractional laser technology, microthermal treatment zones are created with intervening islands of unaffected tissue. Healing time is significantly less, and the energy can safely reach deeper into the dermis.

Hantash et al. demonstrated a unique mechanism of tissue repair with fractional photothermolysis. In 2006 they demonstrated, using an elastin antibody, that damaged dermal content was incorporated into columns of microscopic epidermal necrotic debris (MEND) and shuttled up through the epidermis and extruded in a process of transepidermal elimination. This mechanism, which had not been described with previous laser technologies, explains the elimination of altered collagen in photoaging and scars and was also hypothesized to provide novel treatment strategies for pigmentary disorders, such as melasma, as well as depositional diseases, such as amyloid and mucinoses.

Epidemiology

According to the American Society of Dermatologic Surgery Annual Survey on Dermatologic Procedures, which provides a comprehensive estimate on the total number of cosmetic procedures performed by dermatologic surgeons in the United States, minimally invasive cosmetic procedures have increased by more than 100% since 2012. In 2015 207,000 laser resurfacing procedures were performed, a 36% increase over 2014. The majority of laser skin resurfacing procedures are nonablative and performed on women.

Equipment

As the technology of fractional photothermolysis continues to evolve, new

devices continually come to market. A list of currently available NAFR systems is given in Table 6.1. The table is not comprehensive and, as one can imagine, the devices will change constantly. This section will provide a brief description of a few of the more commonly used devices.

Table 6.1

Nonablative fractional lasers

Device	Manufacturer	Type	Wavelength(s) (nm)
Affirm	Cynosure (Westford, Massachusetts)	Nd:YAG	1440 ± 1320
Clear+ Brilliant	Valeant Aesthetics, Bothell, Washington	Diode	1440
Fraxel Re:Fine	Valeant Aesthetics, Bothell, Washington	Erbium	1410
Fraxel Re:Store	Valeant Aesthetics, Bothell, Washington	Erbium	1550
Fraxel dual	Valeant Aesthetics, Bothell, Washington	Erbium + thulium	1550 + 1927
Icon Lux 1440	Palomar, Cynosure (Westford, Massachusetts)	Nd:YAG	1440
Icon Lux 1540	Palomar, Cynosure (Westford, Massachusetts)	Erbium	1540
Matrix RF	Syneron Candela, Wayland, Massachusetts (Irvine, California)	Diode + bipolar RF	915 + RF
Mosaic	Lutronic (San Jose, California)	Erbium	1550
PicoSure Focus Array	Cynosure (Westford, Massachusetts)	Alexandrite	755

The original nonablative fractional resurfacing system described by Manstein featured a scanning handpiece with a 1500-nm wavelength. The updated, currently available model, the Fraxel re:store (Solta Medical, a division of Valeant Aesthetics, Bothell, Washington), uses a 1550-nm erbium glass laser. The device has tunable settings to adjust the density of the MTZs and energy depending on the treatment. Density can be varied to treat anywhere from 5% to 48%, and energy settings can be adjusted to control depth of penetration from 300 to 1400 μm. Most of the studies available on nonablative fractionated lasers are based on this device.

Solta Medical's second addition, the Fraxel Dual, couples the 1550-nm erbium laser with a 1927-nm thulium fiber laser in one platform. The thulium laser provides a more superficial treatment option and better addresses dyspigmentation, whereas the 1550 nm penetrates deeper to stimulate collagen remodeling. The system increases flexibility, allowing the practitioner to switch between the two lasers to tailor treatment accordingly. Parameters can be adjusted similarly to the Fraxel re:store. Cooling, which helps to minimize procedural discomfort, is also built in with the Fraxel Dual.

The Palomar brand of Cynosure (Westford, Massachusetts) offers the Icon intense pulsed-light (IPL) platform with individual handpieces that attach to a single unit to cover a wide range of uses. The Lux1440 and Lux1540 handpieces provide two wavelength options (1440 and 1550 nm) for fractional nonablative photothermolysis. In addition, the company has developed an XD Microlens for their nonablative laser handpieces. In their study the company claims that, as the dermis is compressed by the optical pins on the handpiece, the pins are brought closer to deeper targets and the interstitial water is displaced from the dermal–epidermal junction into the surrounding spaces. With less water to

absorb, scattering of the laser light is reduced, enabling increased absorption of the light by deeper targets.

The Affirm (Cynosure, Inc., Westford, Massachusetts) is a 1440-nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser device that uses a proprietary Combined Apex Pulse (CAP) technology. This technology creates columns of coagulated tissue surrounded by uncoagulated tissue columns, which purportedly improves treatment efficacy. The Affirm uses a stamping handpiece with two spot sizes and energies that penetrate up to 300 μm in depth. An advance has been the addition of their multiplex technology, which stacks a 1320-nm wavelength with the 1440-nm system, allowing for penetration down to 1000 to 3000 μm. This device is no longer being manufactured, but support and service are still available.

New to this area is a picosecond alexandrite laser with a diffractive lens array which fractionates the 750 to 850 ps pulsed light emitted from a 6-mm spot, thus delivering high-energy light to focused areas and limiting potential complications (PicoSure with Focus Lens Array, Cynosure, Chelmsford, Massachusetts). Brauer et al. have demonstrated the PicoSure's effectiveness in treating epidermal dyspigmentation and mild textural changes associated with photoaging, striae distensae, and acne scars. Of greatest interest is its seeming ability to treat these conditions in individuals of all skin types with low risks of erythema, edema, and hyperpigmentaion, which occur but are self-limited and mild.

Applications

Although NAFR is currently approved by the US Food and Drug Administration for the treatment of benign epidermal pigmented lesions, periorbital rhytides, skin resurfacing, melasma, acne and surgical scars, actinic keratoses, and striae, it has been reported to be used in many other clinical settings (Box 6.1).

Box 6.1

Clinical indications for nonablative fractional resurfacing

- Photoaging
- Scarring (atrophic, hypertrophic, hypopigmented)
- Disorders of pigmentation (melasma, nevus of Ota, drug-induced pigmentation)
- Poikiloderma of Civatte
- Premalignant conditions (actinic keratoses, disseminated superficial actinic

porokeratosis)

- Striae distensae
- Vascular disorders (but not the treatment of choice) (telangiectatic matting, residual hemangioma)

Photoaging

With their seminal study in 2004 using a prototype nonablative fractional resurfacing device, Manstein et al. first demonstrated the clinical effectiveness of fractional photothermolysis by demonstrating improvement in periorbital rhytides. Three months after four treatments with the fractionated device, 34% of patients had moderate-to-significant improvements and 47% had improvement in texture as rated by blinded investigators. Overall, 96% were noted to be "better" post treatment. The skin tightening seen after nonablative fractional resurfacing is similar to ablative resurfacing with tightening within the first week after treatment, apparent relaxation at 1 month, and retightening at 3 months (Case Study 1).

Case Study 1

The Right Patient

A 58-year-old white male with mild rhytides and mild-to-moderate photodamage with scattered facial lentigines presents for consultation. You recommend a series of nonablative fractional resurfacing laser procedures. Six months after the sixth laser procedure, you see the patient back in follow-up. He is delighted with his improvement in both texture and skin tone and subsequently refers a couple of his friends to see you.

This patient is the ideal patient for nonablative fractional resurfacing. These results are typical of the improvement we see in our patients when selected appropriately. Fractional 1927-nm light is best for epidermal dyspigmentation related to photoaging, and the 1550 and 1540 nm wavelengths are best for texture. In this case a combination of wavelengths performed with each visit or alternating devices yields the best possible improvement; 1927-nm light is usually recommended first because of the high degree of rapid improvement in color. Texture is slower to improve.

Subsequent reports have confirmed the efficacy of NAFR beyond just periorbital lines. Wanner et al. showed statistically significant improvement in photodamage of both facial and nonfacial sites, with 73% of patients improving at least 50%. In 2006 Geronemus also reported his experience with fractional photothermolysis, finding it to be effective in treating mild-to-moderate rhytides. Figs. 6.2 and 6.3 show typical improvement in rhytides and pigmentation after treatment with nonablative fractional resurfacing. For deeper rhytides, such as the vertical lines of the upper lip, improvement is also seen but not nearly to the same degree as in ablative approaches.



FIGURE 6.2 Improvement in moderate rhytides 1 month after two treatments with Fraxel 1927 nm. Photo courtesy of Solta Medical.

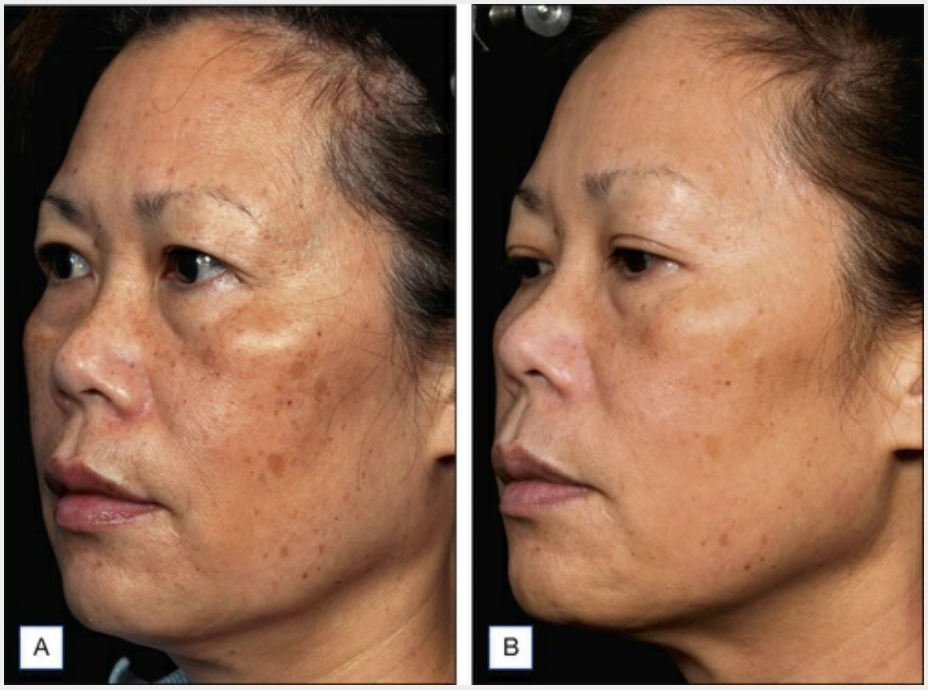


FIGURE 6.3 Improvement in rhytides and dyspigmentation 1 month after three treatments with Fraxel re:store. Photo courtesy of Solta Medical.

NAFR is also considered to be an effective and safe treatment modality for photoaging off the face, including the neck, chest, arms, hands (Fig. 6.4), legs, and feet. These body sites are typically very challenging to treat with other

treatment modalities, given either increased risks of complications (e.g., scarring) associated with ablative technologies or lack of efficacy that has been previously observed with other nonablative devices. Jih et al. reported statistically significant improvement in pigmentation, roughness, and wrinkling of the hands in 10 patients treated with nonablative fractional resurfacing. In our experience, we have found NAFR on all body sites to be very safe when settings are adjusted accordingly.



FIGURE 6.4 Improvement in rhytides and dyspigmentation of the hands 1 month after two treatments with Fraxel re:store. Photo courtesy of Solta Medical.

Scarring

Scarring can induce a tremendous psychologic, physical, and cosmetic impact on individuals. Previous therapeutic modalities in scar treatment include surgical punch grafting, subcision, dermabrasion, chemical peeling, dermal fillers, as well as laser resurfacing with ablative and nonablative devices. Published studies have demonstrated that NAFR can be successfully used in the treatment of various forms of scarring, including acne scarring, with a very favorable safety profile (Fig. 6.5). Mechanistically, fractional photothermolysis allows controlled amounts of high energy to be delivered deep within the dermis, resulting in collagenolysis and neocollagenesis, which smoothes the textural abnormalities of acne scarring. In a large clinical study, Weiss showed a median 50% to 75% improvement of acne scars, using a 1540-nm fractionated laser system after three treatments at 4-week intervals, with 85% of patients rating their skin as improved. Alster showed similarly impressive results in a study of 53 patients with mild-to-moderate acne scarring; 87% of patients who received three treatments at 4-week intervals showed at least 51% to 75% improvement in the appearance of their acne scars. Nonablative fractional resurfacing, in our estimation, is the treatment of choice for facial acne scarring.

Pearl 1

Patients with deep acne scarring or severe rhytides often require high-energy settings, which correlates with deeper penetration of the laser and subsequent remodeling of collagen deeper in the cutis. Lower energy densities are usually recommended to reduce the risk of postinflammatory hyperpigmentation (PIH) in patients with darker skin color.



FIGURE 6.5 Significant improvement in texture and rolling acne scars 2 months after four treatments with Fraxel re:store.

NAFR can also be safely used to treat acne scarring in darker-pigmented patients (Fig. 6.6). A study of 27 Korean patients with skin types IV or V that were treated with three to five nonablative fractional resurfacing treatments revealed no significant adverse effects, specifically pigmentary alterations. Furthermore, all forms of acne scarring, including ice-pick, boxcar, and rolling scars, improved, with eight patients (30%) reporting excellent improvement, 16 patients (59%) significant improvement, and three patients (11%) moderate improvement. With such a good efficacy and safety profile, many clinicians prefer NAFR to ablative fractional photothermolysis when it comes to treating acne scarring. A study by Alexis demonstrated highly effective and low-risk improvement in scarring in patients with darker skin color. Low energy densities appear to reduce the risk of hyperpigmentation, which is uncommon, mild, and usually short-lived.



FIGURE 6.6 One month after five treatments with Fraxel re:store showing significant improvement in acne scarring in a darkly pigmented patient. Photo courtesy of Solta Medical.

NAFR can also be used in the treatment of other types of scars, including hypertrophic and hypopigmented scars. In a study of eight patients with hypertrophic scarring, all patients had improvement in their scars, based on the physician's clinical assessment, with a mean improvement of 25% to 50%. Although the flashlamp-pumped pulsed dye laser (PDL) had long been considered the laser of choice for treating hypertrophic scars, NAFR has shown tremendous promise when compared with PDL. In a study of 15 surgical scars in 12 patients, NAFR outperformed PDL in the improvement of surface pigmentation, texture change, and overall scar thickness.

Haedersdal's group has shown persistent collagen remodeling histologically up to 6 months after NAFR of scars, with 82% of 17 subjects reporting satisfaction with scar improvement at the end of the study. They also studied the mechanism of effect of NAFR on scars, revealing erbium glass laser-induced regulation of matrix metalloprotein (MMP) and interleukin expression. The authors speculate that these alterations on gene expression level could play a role for dermal remodeling, antiinflammatory effects and increased epidermal differentiation. Although more studies are needed, NAFR should be considered as a therapeutic option to be used in conjunction with or as an alternative to PDL.

Treatment of hypopigmented scars has traditionally shown variable efficacy, but current evidence suggests that NAFR may be particularly useful. A pilot study of NAFR laser treatment showed a 51% to 75% improvement in hypopigmented scars in six of seven patients treated. The mechanism of action for this repigmentation has been hypothesized to be secondary to migration of

melanocytes from the pigmented, normal skin into the scar, resulting in blending of the border (Fig. 6.7).



FIGURE 6.7 Improvement of hypopigmented scars 1 month after three treatments with Fraxel 1927 nm.

Melasma

Despite individual reports documenting successful treatment of melasma with NAFR, long-term efficacy of such treatments is still uncertain. The first pilot study by Rokhsar and Fitzpatrick demonstrated an astounding 75% to 100% clearance of melasma in 60% of the patients at 3 months. Only one patient developed transient hyperpigmentation, which resolved. Another study by Goldberg et al. showed "good" improvement of melasma in patients with skin type III. In this study they also showed a decrease in melanocytes by electron microscopy. It has been proposed that dermal content, such as melanin, may be eliminated through the treatment channels through a mechanism termed melanin shuttling. However, other more recent studies have reported only modest improvement in melasma after treatment with NAFR. A larger study of

fractional 1550-nm NAFR in 51 patients by Raulin's group in Germany showed the laser treatment to be no better than sunscreen. Finally, and concerning, a study by Wind et al. showed worsening of hyperpigmentation following NAFR treatments in nine out of 29 patients in a split-face, randomized trial comparing laser with triple topical therapy. Not surprisingly, patient satisfaction was significantly lower on the laser-treated side.

Pearl 2

When treating dyschromia, which is generally more superficial, low energy levels with high-density settings should be used. The density of MTZs is higher at lower energy settings.

More recently, clinicians have been using the 1927-nm thulium fiber laser for the treatment of melasma, but definitive studies are still lacking. In a pilot study by Polder and Bruce, a statistically significant 51% reduction in Melasma Area and Severity Index (MASI) score was observed at 1 month after three to four laser treatments. However, the MASI score at 6 months dropped to 34%. Although initial NAFR reports showed promise in the treatment of melasma, it remains unclear how truly effective these lasers are in treating this chronic, stubborn condition and whether they alter the natural history of the condition. In our experience, NAFR has not been particularly useful nor has it provided long-term improvement in melasma patients.

Actinic keratoses

When treating actinic keratoses, treating the entire surface area of the affected anatomic site, known as field treatment, is preferred to ensure that both clinically visible and microscopic lesions are covered. Initial attempts by Katz et al. to treat these precancerous lesions with fractional 1550-nm laser showed great clinical response, with greater than 73% clearance 1 month post treatment and 55.6% clearance at 6 months. However, posttreatment biopsies revealed histologic persistence, and as a result, it has been recommended that NAFR not be used as a single treatment modality for actinic keratoses. More recently, fractional 1927-nm thulium laser was approved by the FDA for the treatment of actinic keratosis. Geronemus showed that, after a single treatment with the 1927-nm thulium laser, a mean of 63% of actinic keratoses were cleared and after two treatments, 84% of lesions cleared. Definitive data on histologic clearance are still lacking. Although clinical data are early, our own clinical experience has been positive in treating extensive actinic keratoses on the face and scalp. Further studies are needed, specifically ones with histologic analysis, to prove its efficacy.

Pearl 3

The 1927-nm fractionated thulium laser penetrates less deeply than longer erbium NAFR wavelengths and is useful in treating actinic keratoses. It is

especially useful in treating sun-induced lentigines of the face, neck, chest, and hands.

Striae

Although nonablative fractional resurfacing has been FDA approved for the treatment of striae, only a few small studies have examined their effectiveness. Kim et al. performed an early study demonstrating a substantial improvement in the appearance of striae distensae in six female subjects. Furthermore, histologic examination showed an increase in epidermal thickness, collagen, and elastic fiber deposition. Other studies have also shown improvement, albeit modest, in striae appearance. One study showed good-to-excellent clinical improvement in 27% of patients, and another study showed a 26% to 50% improvement in 63% of patients. Furthermore, large-scale studies need to be performed to more clearly define NAFR's effectiveness in treating striae. In our experience the results, when appreciable, have been only modest. A consensus article recommends performing a large test area before having the patient commit to a series of treatments.

Poikiloderma of Civatte and neck dyspigmentation

Poikiloderma of Civatte is characterized by hyperpigmentation and hypopigmentation, atrophy, and telangiectasia. Although PDLs and intense pulse-light sources are considered by many to be the treatments of choice for poikiloderma, fractional nonablative devices at 1550 and 1927 nm are effective in improving overall color and texture of the condition without improving neck laxity.

Other conditions

NAFR has also been used to treat a host of other conditions, including nevus of Ota, minocycline-induced hyperpigmentation, matted telangiectasias, residual fibrofatty tissue after hemangioma involution, recalcitrant disseminated superficial actinic porokeratosis, disseminated granuloma annulare, and colloid milium. Although difficult to gauge clinical response in single case reports, these reports provide evidence on the potential applications of this technology.

Patient selection

The preoperative consultation is crucial to maximize outcomes while minimizing complications. The clinician should assess the patient expectations and goals for treatment during this encounter. Showing patients before and after photos of a typical result can help to set patient expectations regarding the efficacy of treatment. Even so, the patient must also understand that individual responses can vary.

Pearl 4

Take pretreatment photos prior to treatment to document and assess response.

To achieve satisfactory results with NAFR, a series of two or three treatments is required for 1927-nm treatments, and four to six treatments are required to improve texture with 1540- and 1550-nm devices. Typically these procedures are spaced out every 4 weeks, and thus an entire treatment regimen may take 6 months or more to complete (Case Study 2). Those patients who prefer to have dramatic results after only one session are not the right candidates for nonablative fractional resurfacing. Instead, these patients may benefit from fractional ablative resurfacing, which typically requires fewer treatment sessions, but has a much longer recovery. The procedure is painful, but topical anesthesia and forced-air cooling make the procedure tolerable in most. Redness and swelling last an average of 3 days. The brown, sandpaper-like feel seen after treating individuals with epidermal dyspigmentation lasts approximately 5 days.

Case Study 2

Sometimes More Is Better

A 48-year-old male with severe rolling and boxcar acne scars has six nonablative fractional resurfacing treatments with the 1550-nm device. Six months after the last treatment, he comes in wondering what else can be done for his acne scarring. On examination and in comparison with pretreatment photos, you notice improvement in his acne scarring but also some room for further improvement. You recommend another two treatments and see him back 6 months after the 8th treatment. He is extremely pleased and says he noticed significantly more improvement from the final two treatments. This response is predictable because the improvement with nonablative fractional resurfacing is curvilinear. The first two treatments yield very little visible improvement, the next two a bit more, and the final two show the greatest degree of change. Sometimes in patients with bad scarring we perform an additional two treatments but always wait 6 months to see the maximum improvement from the first six before deciding.

NAFR can be performed safely on patients with all Fitzpatrick skin types, but patients with darker skin types should be treated with caution. A study of fractional lasers in the treatment of acne scars by Alajlan and Alsuwaidan and another by Alexis showed a high safety profile in those with skin of color. Although hyperpigmentation was noticed more commonly in darker-skinned patients, particularly when higher fluences were used, this effect was usually transient. To minimize complications in darker-skinned patients, bleaching creams and lower treatment settings are recommended.

It is important to gather a history of prior laser procedures and responses, history of keloids, history of herpes simplex infection, skin phototype, history of PIH, current medications including previous isotretinoin use, lidocaine

allergy, pain tolerance, and anxiety level.

Patients who should not be treated with fractional resurfacing are women who are pregnant or lactating and those with active infection, particularly herpes simplex. How soon NAFR should be performed after use of isotretinoin remains debatable. The original recommendations were to wait at least 6 months after finishing a course of treatment. Recent publications suggest the risk of complications of this procedure after use of isotretinoin is low, and many experts recommend either a short waiting period or no waiting period at all (Prather H et al.) (Box 6.2). Furthermore, individuals with unrealistic expectations should not be treated.

Box 6.2

Contraindications to nonablative fractional resurfacing

- Pregnancy
- Active infection (bacterial, viral, or fungal)
- Recent history of oral isotretinoin (a delay of from 0 to 6 months recommended)
- Patients with unrealistic expectations

The ideal patient for treatment is a fair-skinned (Fitzpatrick types I to III), motivated patient who desires attainable results with a few days of downtime and has realistic expectations (Case Study 3).

Case Study 3

Just Say No

A 76-year-old female comes for a preoperative consultation for nonablative fractional resurfacing. She has been enjoying her summer on the beach and plans to return to her winter home in a few weeks. On exam, she has significant photodamage, sagging, and deep rhytides on a background of tanned skin with numerous lentigines. During the consultation, she makes it clear that because she is leaving soon, she wants to have one treatment that will improve her lines significantly with as little downtime as possible. She has read on the internet that nonablative fractional resurfacing is a great treatment for her aging face with little recovery time and wants to know when she can start.

This patient is clearly not a suitable candidate for nonablative fractional resurfacing. Patients should be counseled that, although NAFR is a highly effective treatment regimen with little downtime, a series of treatments spaced at least a couple of weeks apart is required to achieve those results. In addition, this patient has a distinct tan making her not ideal for laser treatment because

she would be at an increased risk for hyperpigmentation, and more conservative treatment parameters would need to be used. Finally, her sagging skin will not improve with this procedure. She might be a better candidate for ablative fractional resurfacing or nonsurgical or surgical skin tightening.

Pretreatment

All patients should wear a broad-spectrum sunscreen (SPF > 30) and should avoid sun exposure before, during, and immediately after their treatments. There is no evidence that treating with topical hydroquinone for 1 to 2 months prior to nonablative fractional resurfacing decreases the risk of postinflammatory pigmentation in individuals with darker skin types (types IV to VI). Nor is there any scientific proof that topical retinoids need to be discontinued prior to treatment in those with sensitive skin. In spite of this many physicians recommend using hydroquinone and ask patients to discontinue retinoids prior to nonablative fractional resurfacing.

Pearl 5

Topical retinoids do not need to be discontinued prior to nonablative fractional resurfacing. In some patients with sensitive skin, doing so may make treatment more tolerable.

Pretreatment with oral antiviral medications is recommended in those with a history of herpes simplex virus (HSV) infection (Box 6.3). Although some practitioners advocate the routine use of HSV prophylaxis regardless of previous infection, we do not feel that this is necessary. Firoz et al. reported the first three cases of herpes zoster within the distribution of the trigeminal nerve after NAFR. The patients all had a history of chicken pox, and none had received prophylaxis prior to treatment. Patients with a family history of herpes zoster and who have not had shingles themselves may thus benefit from antiviral treatment prior to treatment. Prophylactic antibiotics are not needed for nonablative fractional resurfacing.

Box 6.3

Procedural steps in nonablative fractional photothermolysis

1. Obtain consent and prepare patient:

a. Review risks and limitations of procedure and answer questions.

b. Assess patient expectations.

c. Take preoperative photos.

d. Start prophylaxis for HSV if patient has a history of cold sores.

2. Wash the area to be treated.

3. Gently cleanse skin with alcohol wipe.

4. Apply topical anesthetic ointment and leave on for 1 h prior to the procedure.

5. Perform procedure:

a. Use a skin-cooling device.

b. Apply handpiece perpendicular to skin.

c. Take precaution not to bulk heat.

6. Prepare patient for discharge:

a. Apply cold compresses or ice to minimize swelling.

b. Review posttreatment care.

c. Schedule follow-up appointment.

On the day of the first procedure, serial standardized photographs should be taken to allow patients to observe their treatment progress. Topical anesthesia should be applied 1 hour prior to starting the treatment. Several different anesthetic agents are currently available, including 5% lidocaine; 7% lidocaine/7% tetracaine; 23% lidocaine/7% tetracaine; and 30% lidocaine. In our experience, anesthetic agents with tetracaine induce significant erythema, leading to patient dissatisfaction. We use 30% lidocaine in an adherent ointment base in our practice because it provides the most comfort with the least erythema. To minimize the risk of systemic toxicity from the topical anesthetics, areas no greater than 300 to 400 cm^2 should be treated during each session. Before the treatment, all of the anesthetic should be thoroughly washed off (Case Study 4). Oral anxiolytics and analgesics may be required in a small fraction of patients who cannot tolerate the procedure with topical anesthesia alone. In those who find the procedure too uncomfortable with topical anesthesia, the first thing to do is to leave it on an additional 30 minutes and to be sure to rub it into the skin several times during the 90-minute period to

increase percutaneous penetration. It is remarkable how much better the procedure is tolerated with longer application of the topical anesthesia. Should that still not suffice, we first add ketorolac (Toradol). In more anxious or intolerant individuals we have had success with diazepam and Intramuscular (IM) meperidine (Demerol). Intravenous (IV) sedation is not needed for this procedure. Although metal eye protection is advised for the patient by some, many practitioners recommend that keeping the eyes closed during the procedure is sufficient. All individuals in the treatment room should also wear eye protection. When it comes to selection of treatment parameters, a number of factors need to be considered, including clinical indication, anatomic site, and skin phototype of the patients. In general, studies demonstrate that PIH is less common when fractional resurfacing of darker skin is performed using lower density settings, fewer passes, and longer treatment intervals. Treatment of nonfacial sites should be performed with slightly lower density and fluence settings.

Pearl 6

Large treatment areas (>400 cm^2) should be avoided to reduce the risk of lidocaine toxicity.

Pearl 7

In darker-pigmented patients, energy densities should be decreased; also consider lowering the energy and performing less passes in an effort to reduce the risk of hyperpigmentation.

Case Study 4

Toxicity

A 45-year-old, petite woman weighing 102 lbs presents for nonablative fractional resurfacing of her face, neck, and chest to treat photoaging. She has not had treatment before and has some anxiety over the procedure. After counseling the patient and addressing her concerns, she gives her informed consent and pretreatment photos are taken; 30% lidocaine gel is then applied over the face, neck, and chest.

Prior to her treatment, your schedule begins to run late and you are unable to start her treatment until an hour and a half after the topical anesthesia has been applied. She tolerates the first pass on her cheek but then suddenly becomes agitated and reports significant anxiety. Treatment is immediately stopped, but the woman begins to complain of nausea and perioral paresthesias. You start an infusion of normal saline and closely observe the patient over a couple of hours without further sequelae. Her serum lidocaine levels are elevated at 2 μg/mL.

To avoid this problem, topical anesthesia application should be limited to no more than 1 hour. Furthermore, large treatment areas should be avoided at one

visit. A similar case has been reported in the literature by Marra.

General technique

We find the supine position most comfortable for the patient and practitioner. In this position the practitioner can be seated comfortably with elbows close to 90 degrees to alleviate fatigue and repetitive stress injury. During treatment, patient positioning is crucial to ensure perpendicular application of the laser handpiece. For example, when treating the neck, especially in the submandibular area, it is often helpful to have the chin tilted upward to allow for better exposure.

With the scanning handpiece of the Fraxel systems (Solta Medical, a division of Valeant Aesthetics, Bothell, Washington), we deliver eight passes when treating acne scars, rhytides, and photoaging of the face. We use a double-pass, 50% overlap technique. One linear pass is delivered, the handpiece is brought to a complete stop, lifted, repositioned, and then returned along the same path for a second pass. The handpiece is then moved laterally by 50%, and the technique is repeated until the treatment area is completed. As a result, each area is treated with four passes. For the next four passes, we direct the passes perpendicular to the first treatment to ensure complete and even laser coverage. Dividing the face into four quadrants also helps to manage the treatment area and reduce the risk of overlap or missing a section.

For facial resurfacing, our settings are individualized according to patients' needs and tolerability. We often start with energy levels between 40 and 50 mJ and a treatment level of 6 to 8 (Table 6.2). The settings are often increased during subsequent visits if tolerated.

Table 6.2

Recommended treatment parameters

Device	Indication		Energy (mJ)	Pulse width (ms)	Treatment level*	Number of passes
1550 nm (Fraxel)	Facial resurfacing for wrinkles, acne, and other scarring but not melasma/dyspigmentation		40–70	—	6–10	8
Nonfacial resurfacing	—		20–40	—	6–10	—
Melasma	—		10–20	—	4–6	8
1927 nm (Fraxel)	Facial resurfacing		10	—	5	8
Nonfacial resurfacing	—		10	—	3	8
Melasma	—		5–10	—	2–4	8
1440 nm (StarLux/Icon)	10 mm tip	Facial resurfacing	25–70	7–10	—	2
	15 mm tip	Facial resurfacing	6–10	7	—	1–3
1540 nm (StarLux/Icon)	10 mm tip	Facial resurfacing	40–70	10–15	—	3–6

	15 mm tip	Facial resurfacing	10–15	10–15	—	3–4
	15 mm tip	Melasma†	5–12	10–15	—	2–5
1440 nm (Affirm)	10 mm tip	Facial resurfacing	3–5	—	—	2
	14 mm tip	Facial resurfacing	3–4	—	—	2
755 nm (PicoSure Focus Array)	6 mm	Facial resurfacing for wrinkles, scars and dyspigmentation	0.71 J/cm² 500–750 ps	—	—	6–8
	—	—	—	—	—	—
	—	—	—	—	—	—

*Treatment level for darker skin types (IV to VI) should be decreased to reduce the risk of hyperpigmentation.

†For treating.

For stamping handpieces, the fractionated energy is delivered according to the tip size. For example, with the StarLux system (Cynosure, Westford, Massachusetts) and the 15-mm Lux1540 handpiece, three to four passes are generally delivered with a 50% overlap in both directions. The handpiece should be lifted off the skin between each pulse, and pulse-stacking is not recommended. For facial resurfacing with the Lux1540 15-mm tip, we recommend using 10 to 15 mJ per microbeam with a pulse width of 10 to 15 ms. Treatments with the picosecond focused lens array are better tolerated and require shorter time of anesthesia application to limit discomfort. Thirty minutes usually suffices. A series of passes is recommended with a total of several thousand pulses delivered per treatment. Patients are treated every 4 to 6 weeks for up to six treatments or until a satisfactory result has been achieved.

Cooling

A cooling device used in conjunction with the NAFR laser device should be standard for all treatments. A popular forced-air cooling device, the Zimmer Cryo (Zimmer Medizin Systems, Irvine, California) increases patient comfort significantly. Some laser systems now also come with a built-in cooling device. In a study of 20 patients, 19 noted significant pain reduction with the addition of a cooling device.

Posttreatment

Upon completion of the treatment, patients are advised to ice their skin for at least 10 minutes and then periodically over the next few hours. Not only does this help with patient comfort, but it also reduces postprocedure swelling. Swelling typically lasts 1 to 3 days, but in the rare individual it can last for a week. Although swelling is hard to predict prior to the first treatment, the pattern usually remains constant during a series of treatments. Patients who do

not swell after the first treatment tend not to swell with subsequent treatments. Erythema develops immediately afterwards in all treated patients (Fig. 6.8) and typically resolves in 3 days. Use of noncomedogenic moisturizers is also recommended. Patients are advised to wear sun protection for several weeks after their treatment to reduce the risk of hyperpigmentation. In those with an increased risk of hyperpigmentation, hydroquinone may be started immediately after the procedure. We routinely wait to start lightening agents until we see the first signs of postinflammatory pigmentation, which is usually around day 21 post treatment. Alster et al. showed that a light-emitting diode device (Gentlewaves, Light BioSciences, Virginia Beach, Virginia) decreases erythema intensity and duration following treatment, although the precise mechanism of action is unclear.



FIGURE 6.8 Prior to treatment (**A**) and immediately after nonablative fractional resurfacing (**B**) demonstrating erythema.

Safety and complications

NAFR is a well-tolerated procedure with an excellent safety profile. Fisher and Geronemus studied the immediate and short-term side effects, showing a favorable side effect profile. In their study of 60 patients with skin types I to IV, all patients expectedly developed erythema immediately post treatment, which in most patients resolved in 3 days. Xerosis occurred in 86.6% of patients, usually presenting 2 days after treatment and resolving by day 5 or 6. This was minimally bothersome and responded well to moisturization. Other frequently

reported posttreatment side effects were transient and included facial edema (82%) and flaking (60%). Small, superficial scratches were also reported in 46.6% of patients. These scratches, which all resolve without sequelae, are thought to be related to tangential application of the handpiece or pulse stacking by inexperienced users. Pruritus (37%) and bronzing (26.6%) are also common side effects of treatment.

Perhaps the most valuable finding from this short-term study was the impact on the patient's quality of life; 72% reported limiting social activities by an average time of only 2.1 days, which is in stark contrast to the downtime seen with the conventional resurfacing laser. The most commonly attributed reasons were erythema and edema. The treatments were well tolerated, with an average pain score of 4.6 on a scale of 1 to 10.

Given that NAFR was specifically developed to minimize the extent of complications, long-term complications are also extremely rare. Graber et al. performed a large-scale study looking at the complications and long-term side effects of NAFR. Consistent with Fisher and Geronemus' study, they also reported a low short-term complication rate. In their study of 422 patients with a total of 961 treatments, the most common complications were acne eruptions (1.87%), HSV outbreaks (1.77%), and erosions (1.35%), all of which occurred with lower frequency than after ablative procedures. Acne outbreaks were more likely to occur in patients who were acne-prone and thus oral antibiotic prophylaxis may be considered in some patients. Other uncommon complications included prolonged erythema and edema.

When similar treatment parameters were used across different skin phototypes, complications were more likely to occur in those that were more darkly pigmented, especially with regard to PIH. Although an uncommon complication (0.73%), PIH lasted an average of 51 days, significantly longer than any other complication. Studies have shown that, with proper titration of settings, darker-pigmented patients can be treated more safely. Although both energy and MTX density determine treatment level, Chan et al. provided the first evidence that density of MTZs may specifically increase the risk for PIH. By reducing the density and lengthening the treatment interval, the risk of PIH in darker-skinned patients can be significantly reduced. Sunscreen and hydroquinone use should be implemented both before and after treatment to minimize this risk even further.

Although complications, especially long-term ones, are extremely rare, patients should be educated to expect typical side effects, including posttreatment erythema, edema, dry skin, and desquamation (Box 6.4).

Box 6.4

Complications associated with nonablative fractional resurfacing

More common complications	Less common complications
• Acneiform eruptions • HSV outbreaks	• Prolonged erythema • Prolonged edema

• Erosions • Postinflammatory hyperpigmentation	• Recall erythema • Dermatitis • Impetigo • Scarring • Varicella zoster virus • Lidocaine toxicity

Advances in technology

The field of fractional resurfacing is relatively new, with advances in treatment parameters and new applications for the technology evolving seemingly every month. Since the first fractional resurfacing device was used in 2004, laser systems have continued to be refined and updated. For example, the Fraxel re:store (Solta Medical, a division of Valeant Aesthetics, Bothell, Washington) provides deeper penetration, greater percentage of skin covered, and a variable spot size over the original SR750 model. Nonablative laser wavelengths have also been broadened significantly with systems using picosecond 755-nm alexandrite technology, infrared (LuxIR fractional, Cynosure, Westford, Massachusetts), and now even radiofrequency. the eMatrix system (Syneron Candela, Wayland, Massachusetts), a fractionated bipolar radiofrequency device, uses a new concept of sublative rejuvenation. The technology is purported to cause limited epidermal disruption while creating a wider, conical injury zone within the dermis. Although few clinical studies have been performed with this newer technology, it is clear that technologic advances in fractional photothermolysis will continue to be made as the field evolves even further.

Over-the-counter devices—the future?

Given the tremendous success of in-office devices, several companies have developed their over-the-counter nonablative fractional counterparts that are designed for photorejuvenation. In spite of early optimism, to date, acceptance of these technologies has been disappointingly limited. PaloVia Skin Renewing Laser (Cynosure, Westford, Massachusetts) was the first handheld, fractional, nonablative diode laser (1410 nm, 15 mJ, 10 ms pulse duration) to be FDA cleared for the reduction of fine lines and wrinkles around the eyes. With a demonstrated depth penetration of approximately 250 μm, this device has been shown in two pivotal studies to improve facial wrinkle score by at least one grade among 90% of patients after 4 weeks of daily use. On self-assessment in the pivotal phase study, 87% of patients felt they had reduction in the degree of their wrinkles.

Another home-based photorejuvenation device, RéAura (a collaborative effort between Solta Medical, a division of Valeant Aesthetics, Bothell, Washington and Philips, Einthoven, Netherlands) is currently undergoing further studies and is pending approval by the FDA. This home version of the original Fraxel re:store (Solta Medical, a division of Valeant Aesthetics, Bothell,

Washington) is a 1435-nm laser that uses a high-speed scanner and produces fractionated microscopic skin injury at approximately 200 μm. A study of 80 patients who received twice-weekly treatments to face, neck, chest, and arms for 8 to 12 weeks revealed statistically significant improvement in overall appearance, fine lines, pigmentation, age/sun spots, texture, firmness, and radiance at 1 and 4 weeks after completion of the course of treatment.

Despite the advances made in home fractionated technologies, home devices simply cannot and will not replace office-based nonablative fractionated devices. Although modest improvement in wrinkles and texture may be observed, the degree of dermal injury cannot match office-based more aggressive devices. Home fractionated devices also carry a significant risk of potential misuse, but the companies that make these devices make every effort to prevent that possibility.

Advanced topics: treatment tips for experienced practitioners

Many patients have both the pigmentary changes and rhytides associated with photoaging. A hybrid approach combining two nonablative fractional resurfacing wavelengths optimizes outcomes. Alternating 1927-nm with 1550-nm treatments addresses both concerns (Case Study 5). An alternative approach uses IPL to address the dyschromia and uneven pigmentation of photoaging, whereas 1550-, 1540-, or 1440-nm NAFR devices address wrinkling. Combining technologies in what are sometimes called "megasessions" produces striking improvement in texture and color. Some combinations include NAFR preceded by Q-switched alexandrite laser, Q-switched Nd:YAG laser, long-pulsed green laser, or IPL. In our own study, the addition of a MaxG IPL (Cynosure, Westford, Massachusetts) treatment immediately prior to the Lux1540 nonablative resurfacing device yielded significant improvement in photoaging scores when rated by blinded physicians.

Case Study 5

Combination Treatment

A 62-year-old female with numerous lentigines and mild rhytides comes in for cosmetic consultation. She has heard that IPL treatment would improve her brown spots. Although you agree that IPL would significantly improve her dyspigmentation, you recommended the 1550-nm nonablative fractionated device alternating with the 1927-nm device instead. Using this treatment strategy, you realize that you can give her a "bigger bang for her buck" and also improve her rhytides. She does six treatments (three with each laser) over 6 months and has a very dramatic response. She is extremely pleased with the treatment results.

Conclusions

The science of NAFR has revolutionized our treatment strategies for a host of dermatologic conditions. Coupled with a very favorable side effect profile and minimal downtime, this relatively new technology will continue to gain in popularity. With new devices and modifications to current systems emerging constantly, its applications will also continue to evolve and broaden. Clinical studies demonstrating efficacy and further scientific scrutiny will help to continue to advance this technology.

Check online video (Video 6.1)

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7

Laser resurfacing

Jason N. Pozner, Barry E. DiBernardo, Lawrence S. Bass



Summary and Key Features

- Laser resurfacing is a very popular procedure.
- A variety of carbon dioxide, erbium:yttrium-aluminum-garnet, and yttrium-scandium-gallium-garnet lasers are included in this category.
- Full field means 100% of the treated area is removed to the selected depth.
- Fractional means discontinuous portions of the treated area are removed.
- Hybrid fractional lasers are a combination of ablative and nonablative fractional resurfacing.
- Recovery time is linked to depth and percentage of surface damaged.
- Fractional treatments have less downtime than full-field treatments.
- Experience with these lasers is important to outcomes.
- Posttreatment care is very important.
- Complications can arise with all of these laser modalities.

Introduction

Laser resurfacing is a very popular procedure in the United States and worldwide. Data from the American Society of Aesthetic Plastic Surgery collected yearly from core specialists since 1997 through 2015 have shown the rise, fall, and rise again of this procedure as devices have been introduced. In 2015 more than 418,000 full-field and fractional laser resurfacings were

performed in core offices, making this the eighth most popular surgical or nonsurgical procedure (Table 7.1).

Table 7.1

American Society for Aesthetic Plastic Surgery top 10 procedures for 2015

1. Toxins—Botox, etc.
2. Hyaluronic acid
3. Laser hair removal
4. Chemical peel
5. Microdermabrasion
6. IPL
7. Nonsurgical skin tightening
8. Laser resurfacing—full field and fractional
9. Liposuction
10. Sclerotherapy

IPL, Intense pulsed light.

In the mid-1990s carbon dioxide lasers were extremely popular, but toward the turn of the 20th century they fell out of favor and were somewhat replaced by nonablative technology. Laser resurfacing resurged after 2004 and the introduction of fractional lasers.

History

Lasers were introduced into the plastic surgery and dermatology world initially for the treatment of vascular lesions. The introduction of the carbon dioxide laser for skin resurfacing in the mid-1990s rapidly became popular and replaced chemical peels and dermabrasion in many practices. The carbon dioxide laser has a wavelength of 10,600 nm, has an absorbing chromophore of water, and is used to vaporize tissue. Continuous mode lasers were initially used, but complications due to excessive depths of ablation and thermal damage led to advances to deliver short laser pulses to the skin to minimize complications. Competing technology delivered either short pulses, each of which contained enough energy to cause tissue ablation (Ultrapulse laser, Lumenis lasers, Yokneam, Israel) or an optomechanical flashscanner used to scan a continuous laser beam in a spiral pattern (Silk-touch and Feather-touch lasers, Lumenis lasers, Yokneam, Israel). Both methods created a tissue exposure time of less than 1 ms, which allowed tissue ablation with limited residual thermal damage of approximately 75 to 100 μm. Short-term results of eradicating wrinkles and tightening lax tissue were excellent, but longer-term follow-up showed hypopigmentation in a large percentage of patients. These pigmentary complications and the considerable downtime created for the patient led to the demise of "full-field" carbon dioxide laser resurfacing around the turn of the century.

Erbium:yttrium-aluminum-garnet (Er:YAG) lasers (2940 nm) were introduced around 2000 and marketed for superficial resurfacing. Erbium lasers have a higher water absorption coefficient than carbon dioxide lasers

(approximately 10 times more efficient) and ablate tissue with much less thermal damage (5 to 10 μm). Initial machines were low-powered, lacked pattern generators, and needed a considerable number of passes and treatment time to achieve deeper depths of ablation. Subsequent systems had more significant power and could be used for efficient deeper resurfacing. There is a linear relationship between the energy delivered and depth of ablation, with approximately 3 to 4 μm ablated per joule of Er:YAG laser fluence delivered. Complications were fewer, yet downtime appeared to be similar to that of carbon dioxide systems. Conclusions of comparative studies were that the combined depth of ablation and coagulation was the determining factor in length of recovery. Combination systems of carbon dioxide and Er:YAG lasers were popular for a short time (Derma-K, Lumenis lasers, Yokneam, Israel) with the beams being delivered either sequentially or at the same time.

Variable or long-pulse Er:YAG lasers (Sciton Inc., Palo Alto, California) allow control over the amount of residual thermal injury produced for a given amount of tissue removal. These variable pulse Er:YAG systems seem to produce skin tightening and wrinkle reduction similar to carbon dioxide lasers, with a much shorter period of erythema and much lower risk of hypopigmentation. These devices are currently very popular.

Other wavelengths for skin resurfacing have been introduced (2780 and 2790 nm) (Cutera Lasers, Palomar Lasers), which allow variable degrees of thermal damage and ablation settings, but have not had significant commercial success. Plasma skin resurfacing uses nitrogen plasma energy to coagulate a very controlled depth of skin. Healing times and results appear to be similar to Er:YAG lasers. These devices were popular for some time but were removed from the marketplace due to financial problems of the manufacturer. They were recently reintroduced into the market.

In 2004 Manstein et al. introduced the concept of fractional photothermolysis. Full-field or traditional laser resurfacing as described previously removes the entire skin surface in the area being treated, with depth of injury depending upon energy level, whereas fractional laser resurfacing treats a small "fraction" of the skin at each session, leaving skip areas between each exposed area (Fig. 7.1). This was first performed commercially using nonablative fluences at 1550 nm (Solta Medical, Mountain View, California). These nonablative fractional lasers created a column of thermal damage with intact epidermis. Healing occurred from deeper structures, as well as from adjacent structures. This differs from full-field resurfacing in which healing occurred from only deeper structures. Deeper treatments (i.e., to the reticular dermis) can safely be performed using this approach than would be tolerated using a full-field treatment. Advantages of this approach include avoidance of an open wound and very low risk of pigment disturbance or scarring. Disadvantages have included the need for multiple treatments and somewhat less clinical response than with full-field ablative resurfacing. Since the introduction of the original system, there have been many manufacturers that have introduced similar nonablative fractional devices with wavelengths of 1440, 1540, and 1550 nm. These devices differ in power output, spot size, density, etc., and comparisons

of clinical efficacy are difficult, yet similar degrees of tissue injury should produce similar clinical results.

Pearl 1

Full-field resurfacing means the entire top layer of the skin (to whatever depth is specified) is removed.

Pearl 2

Fractional resurfacing means a "fraction" or percentage of the skin is removed (to whatever depth is specified).

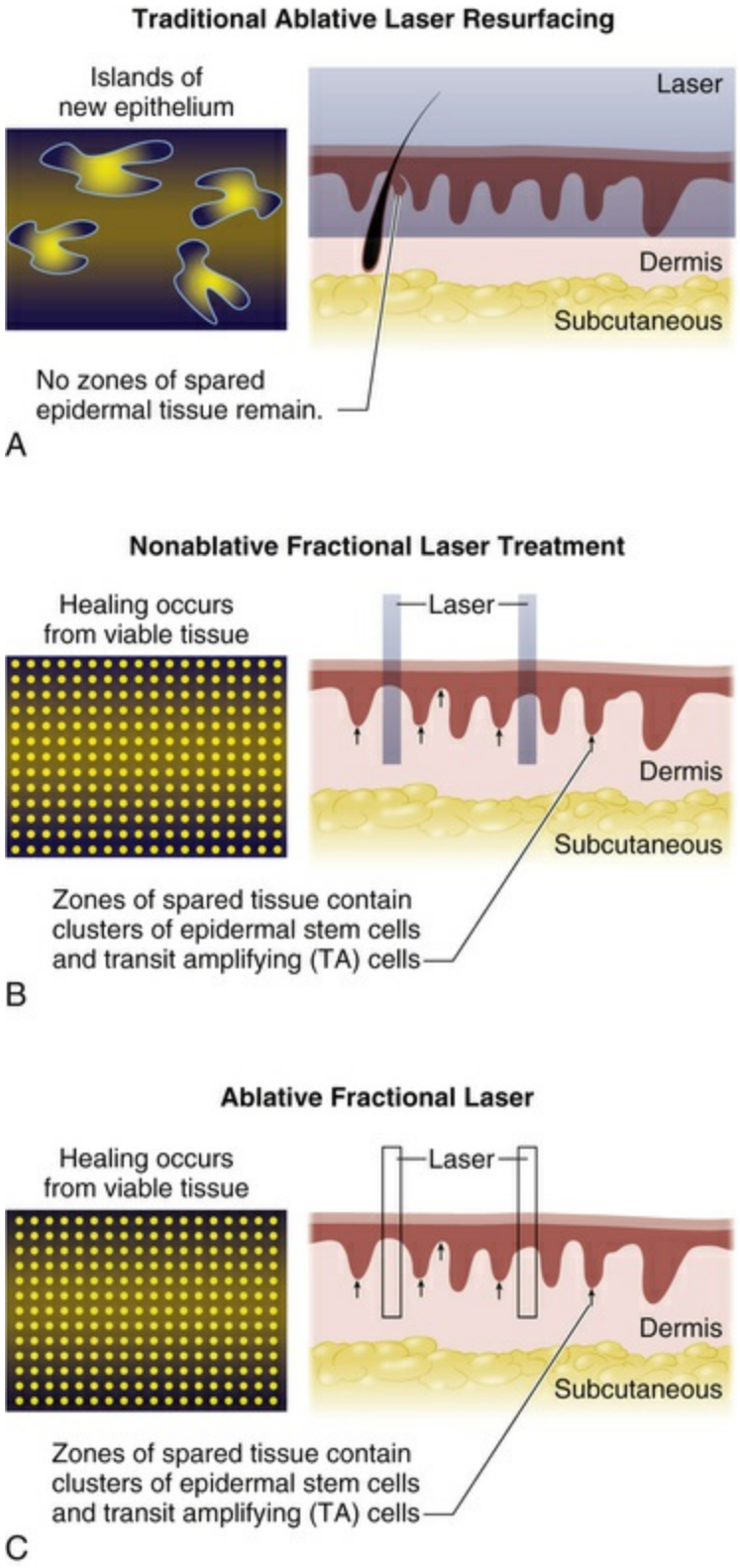


FIGURE 7.1 **A,** Traditional ablative laser resurfacing (full field). **B,** Fractional treatment. **C,** Ablative fractional laser treatment.

Fractional ablative resurfacing with carbon dioxide, Er:YAG, and yttrium-scandium-gallium-garnet (YSGG) systems was introduced with the intent of providing more significant results than nonablative fractional systems, while achieving shorter healing times and complications when compared with full-

field ablative systems (see Fig. 7.1). These devices differ not only in wavelength but in system power, spot size, and amount of thermal damage created adjacent to and deep to the ablated hole. One popular Er:YAG system, the Sciton ProFractional, allows one to vary the amount of thermal damage similarly to their full-field system. Other newer carbon dioxide fractional lasers allow variation of the thermal damage zones (Deka Medical), whereas others allow superficial and deeper penetration with a single scan (Syneron, Yokneum, Israel). As with the nonablative fractional systems, direct comparison between devices is difficult because devices differ in power output, spot size, density, and degree of thermal damage, but similar degrees of injury should produce similar clinical results.

The newest wavelength to be introduced into the fractional arena is the Thulium (1927 nm) by Solta Medical. This nonablative fractional device is especially effective in removing superficial pigment and treating actinic keratosis.

The newest fractional laser on the market is a hybrid fractional laser made by Sciton called the Halo. This is a very interesting device because it allows zcoincident delivery of first their Er:YAG fractional laser then a nonablative 1470-nm pulse in the same hole. This device is very efficacious and creates minimal healing times.

Patient selection

Patient selection and a clear understanding of potential complications are important to achieving consistent results. The most common indications for both full-field and fractional laser resurfacing are superficial dyschromias, dermatoheliosis, textural anomalies, superficial to deep rhytides, acne scars, and surgical scars. Other conditions that may respond favorably include rhinophyma, sebaceous hyperplasia, xanthelasma, syringomas, actinic cheilitis, and diffuse actinic keratoses. Dyschromias, such as melasma, have been successfully treated with fractional resurfacing, but results are not consistent. The usual area for resurfacing is the face, but body and neck skin may be treated with variations of the technique. Nonfacial areas lack the appendages necessary for skin rejuvenation, and treatment must be performed nonaggressively to avoid complications. These devices are generally used with patients with Fitzpatrick skin types I to IV but can be used in skin types V and VI, with modification of technique.

Patient assessment starts at the consultation with observation of the patient's Fitzpatrick skin type, ethnicity, and pathology to be treated. For example, deep acne scarring will not be successfully treated with a single treatment of nonablative fractional treatment, but mild textural issues may respond to superficial treatment. The next assessment is of the patient's tolerance of healing period “downtime.” A busy executive with no urgency for end point of clinical results may be able to be treated only with a series of no-downtime nonablative fractional therapy, whereas the bride's mother looking for maximum improvement in a short time to look her best for her daughter's wedding may

need a single session with more aggressive treatment. The last parameter is one not usually discussed in medical journals or book chapters: patient finances. A deep full-field resurfacing performed under general anesthesia will be more expensive for the patient then a superficial treatment performed with topical anesthesia. However, in patients with deep rhytides a more aggressive procedure under general anesthesia may be more cost-effective than multiple more superficial treatments. Another consideration is laser resurfacing while patients are undergoing other procedures, such as facelift, abdominoplasty, or aesthetic breast surgery. These patients often have built-in downtime from other procedures and have the recovery time available for deep resurfacing.

Pearl 3

Patient assessment starts at the consultation with observation of the patient's Fitzpatrick skin type, ethnicity, and pathology to be treated.

Pearl 4

Assessment of patients' ability to subject themselves to "downtime" of a healing period is important.

Many of us with various devices in our offices can offer patients a plethora of treatment options, and this can be very confusing to the patient. An effective consultation will encompass a thorough evaluation of the pathology and provide options to the patients in terms of downtime, efficacy, risks, and cost.

Expected benefits and alternatives

The potential for improvement depends upon the device used and depth and degree of injury produced. There are many options for superficial treatment of texture issues, dyschromias, and superficial rhytides, including nonaggressive full-field resurfacing with Er:YAG, CO_2, YSGG, or plasma devices or with nonablative or ablative fractional treatment. Many practitioners are using combination therapy with superficial full-field treatment combined with fractional treatment, whereas others are combining fractional ablative and nonablative therapy and others again are using intense pulsed-light (IPL) therapy combined with resurfacing. Other treatments that may yield similar results for superficial pathologies include light chemical peels, such as 15% to 30% trichloroacetic acid (TCA), IPL devices, and Q-switched lasers (532 nm for dyschromias). We prefer lasers and plasma devices to chemical peels, owing to the uniformity and predictability of treatment because the device produces tissue effects with minimal variability from pulse to pulse or patient to patient. The learning curve with lasers is less than with chemical peels, due to the predictability of the treatment. Expert chemical peelers may get similar results to laser treatment at a fraction of the laser cost, but years of experience are necessary to achieve consistency of results. IPL devices may be used to treat

dyschromias and superficial vasculature but require multiple sessions and do not address textural issues or rhytides. Q-switched lasers (532, 694, and 755 nm) are excellent at removing dyschromias in one session but have resultant erythema that lasts for up to 10 days.

Pearl 5

The potential for improvement depends upon the device used and depth and degree of injury produced.

More significant pathology requires deep treatment to achieve results in a single session. There is still a question of whether repeated superficial therapies with ablative fractional devices will achieve similar results to one more aggressive full-field session. Deep ablative full-field resurfacing may be performed with either Er:YAG or CO_2 systems. YSGG in full-field mode and plasma devices do not ablate deep enough to treat more significant pathology. Acne scars appear to respond better to fractional therapy than to full-field therapy. Alternative treatments may be deeper chemical peels, such as phenol, or dermabrasion. The authors think that lasers provide more consistent and reproducible results than chemical peels or dermabrasion.

Lasers and technical overview

As discussed previously, current devices used for ablative laser resurfacing include carbon dioxide, Er:YAG, and YSGG lasers, in both full-field and fractional modes, and nonablative devices in a variety of wavelengths, including 1440, 1540, 1550, and 1927 nm (Table 7.2). Some machines offer upgradeable expandable platforms in which full-field devices and fractional devices are available in one machine, whereas other companies offer only isolated full-field or fractional devices.

Table 7.2

Types of ablative systems

Type of laser	Wavelength		
Full field	10,600 CO_2	2940 erbium	2780 YSGG
Ablative fractional	10,600 CO_2	2940 erbium	2780 YSGG

CO_2, Carbon dioxide; *YSGG*, yttrium-scandium-gallium-garnet.

Carbon dioxide full field

Pulsed or scanned full-field carbon dioxide lasers were very popular from 1995 to approximately 2000. These devices were powerful, with a typical single pass ablating approximately 75 μm and creating thermal damage of approximately

75 to 100 μm. This residual area of desiccated tissue reduced the amount of absorbing chromophore (water) and made subsequent passes less efficient, and in fact excessive stacked passes acted as a heat sink and created excessive thermal damage and the potential for scarring. Up to three passes were usually performed with the original carbon dioxide resurfacing lasers, owing to diminishing efficiency of tissue removal and rapidly increasing risk of complications. The ablated tissue and underlying thermal damage led to long-term collagen changes and tissue remodeling. Healing time with deep full-field carbon dioxide laser resurfacing took approximately 10 to 14 days and caused erythema that typically lasted a few months. Complications of prolonged erythema and delayed hypopigmentation occurred and led to diminished use of these devices. Further complications will be addressed in the complications section.

Erbium:yttrium-aluminum-garnet full field

The Er:YAG laser (2940 nm) has an absorption coefficient 10 times greater than the carbon dioxide laser and ablates tissue more efficiently and leaves less residual thermal damage (5 to 10 μm). There is a linear relationship between energy density (fluence) delivered and tissue ablated with 3 to 4 μm of tissue removed per J/cm^2, and multiple passes can be used to produce deeper tissue removal without additive residual thermal injury. This leads to recovery time of deep full-field Er:YAG laser resurfacing of 7 days to full epithelialization followed by 3 to 6 weeks of erythema. Superficial and deep resurfacing can be performed with these devices with increasing results and increasing recovery times with deeper treatments (Figs. 7.2 and 7.3). Complications including hypopigmentation are less than with carbon dioxide laser full-field resurfacing.



FIGURE 7.2 Periocular treatment—a 38-year-old female (**A**) before and (**B**) 3 years after full-field variable pulse width Er:YAG laser treatment of the lower lids.



FIGURE 7.3 Perioral treatment—a 60-year-old woman (**A**) before and (**B**) 2 years after full-field perioral resurfacing with a variable pulse width Er:YAG laser.

Variable pulse Er:YAG systems allow a shorter ablative pulse followed by longer subablative pulses to create increasing thermal damage. These devices are typically used to achieve carbon dioxide laser-like results, but without the long healing times and complications, such as hypopigmentation.

Yttrium-scandium-gallium-garnet full field

The 2790-nm YSGG (Pearl: Cutera, Brisbane, California) provides half the affinity for water as the Er:YAG laser at 2940 nm. This device in full-field mode causes ablation of approximately 20 to 30 μm and residual thermal damage of approximately 20 μm per pass. Healing times and downtime are a few days. Deeper resurfacing is not performed with this device.

Plasma resurfacing

Plasma resurfacing systems create tissue ablation and thermal damage but also a coagulated eschar that remains in place as a biologic bandage until underlying skin is reconstituted. Complications and recovery are reported to be less than for aggressive laser skin resurfacing. This device was recently reintroduced to the marketplace (Energist NA Inc., Nyack, New York).

Nonablative fractional

Nonablative fractional resurfacing involves the simultaneous or sequential placement of multiple small spots of laser light onto the surface of the skin with intervening skip areas of unexposed skin. The chromophore used is water, and the wavelengths used are 1440, 1470, 1550, and 1540 nm. The lasers create a column of tissue coagulation from 300 to 1200 μm and are called microthermal zones (MTZs). This subject is covered in Chapter 6, and readers are referred there for a more extensive discussion.

Fractional ablative technology

Ablative fractional resurfacing can be performed with carbon dioxide, Er:YAG, and YSGG devices. There are many devices available from many well-known laser manufacturers. Differences in devices are the mode of spot placement—scanning versus stamping, size of holes (width and depth) created, and power output of devices. Differences between fractional carbon dioxide systems, fractional Er:YAG systems, and YSGG systems are similar to their full-field counterparts in that the carbon dioxide systems cause more residual thermal damage. Newer Er:YAG systems have variable pulse widths, which cause carbon-dioxide-like thermal damage. Reepithelialization is quicker than with full-field ablation, and recovery time varies from hours to a few days, depending upon depth and density of treatment.

Both ablative fractional and nonablative fractional devices are used to treat acne and other scars (Fig. 7.4). Multiple treatments are needed, and there is no current consensus as to the best technology for this at present. It was very common in our offices to perform combination treatment with superficial full-field Er:YAG resurfacing followed by Er:YAG fractional treatment. The superficial Er:YAG treatment improves skin texture and minor irregularities, whereas the fractional treatment is useful for collagen remodeling. This treatment regimen was replaced by treatment with a hybrid fractional laser with or without simultaneous IPL treatment.



FIGURE 7.4 **A** and **B,** This patient had scars of the forehead treated with ablative fractional resurfacing.

As fractional CO_2 laser treatments have been pushed to higher and higher coverages in an attempt to maximize efficacy, healing times predictably have increased. More importantly, complications, such as scarring and hypopigmentation, have been observed at coverages in excess of 45%. CO_2 resurfacing histology consistently shows a significant component of tissue ablation and coagulation. Efficacious resurfacing is believed to require a significant component of both. One strategy that has been explored to increase coverage percentage and maximize efficacy involves a combination treatment with ablative Er:YAG fractional and nonablative fractional exposures in a single treatment session. This provides a component of largely ablative exposure with the fractional Er:YAG treatment and a component of coagulation with the nonablative fractional treatment. Rather than being spatially overlapped as in a fractional CO_2 MTZ, the coagulation and ablation are separated. Coverages up to 65% are routinely applied with only a modest increase in healing time and

erythema compared with fractional Er:YAG treatment alone and somewhat less than that reported for fractional CO_2. Advantages of this approach include preservation of the short recovery and low incidence of complications seen with fractional Er:YAG treatments and the potential for significant improvement even in perioral rhytides. Disadvantages include the need for two lasers or a single laser platform that offers both options and the time-consuming nature of the treatments (Fig. 7.5).

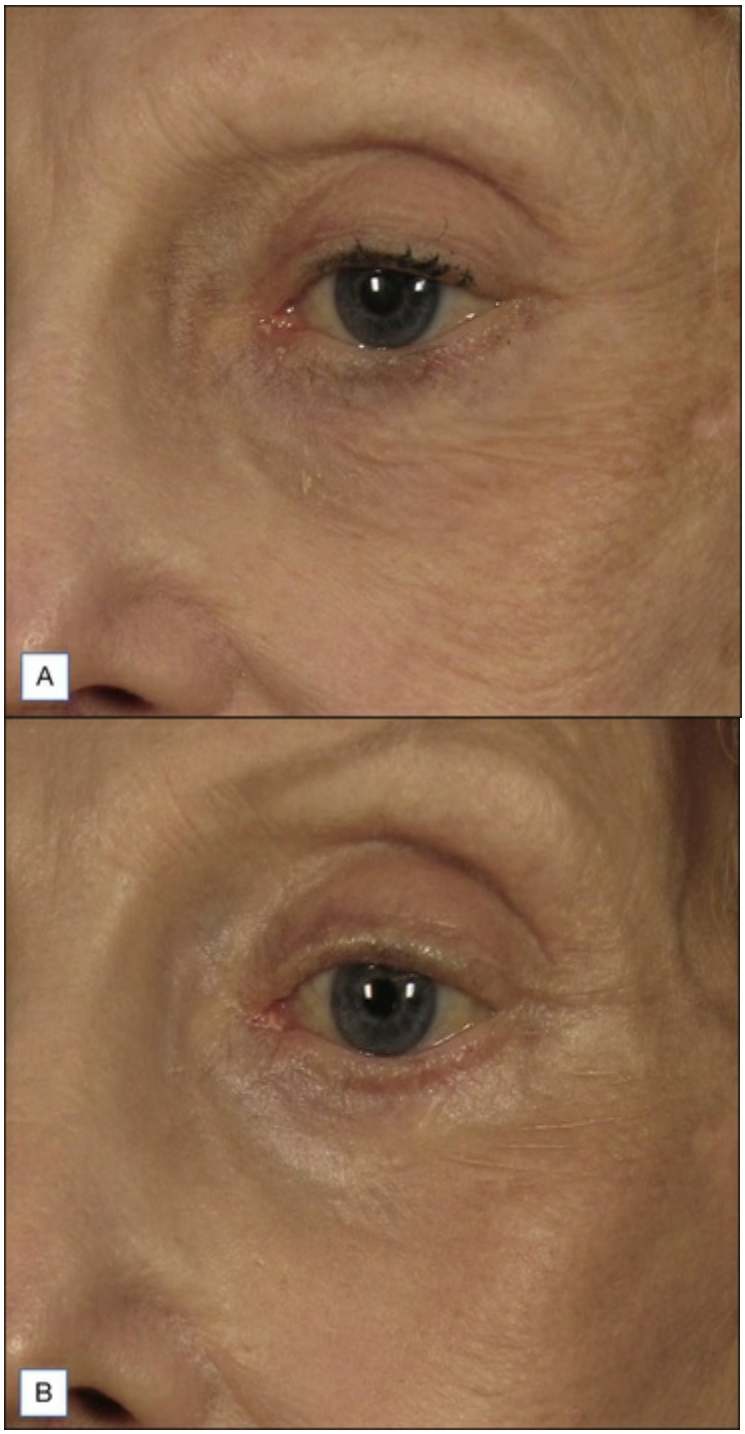


FIGURE 7.5 A 68-year-old woman with combination fractional

Er:YAG resurfacing and fractional 1540-nm nonablative resurfacing with total coverage of 55%. Time to epithelialization was 4 days. Duration of erythema was 11 days. **A,** Before and (**B**) 6 months after treatment.

This combined treatment regimen led to the introduction of the Sciton Halo hybrid laser. This device allows either nonablative fractional resurfacing with a 1470-nm laser or coincident treatment with both a fractional ablative wavelength (2940 nm) and a fractional nonablative wavelength 1470 nm. Treatment with this device has very little downtime, and the results of coincident ablative/nonablative resurfacing on pigment, texture, and pores appear to surpass that achieved with either nonablative or ablative fractional resurfacing alone (Fig. 7.6). Fewer treatments are needed then with other fractional devices to achieve similar results. Newer protocols with this device are for combined treatment with an IPL device, and initial results we have seen appear to be better then non-combined treatments.



FIGURE 7.6 **A,** Before and (**B**) 30 days after treatment with a hybrid fractional laser.

Overview of treatment strategy

Laser safety

Laser safety is critical to both practitioner and patient. There are excellent published guidelines on laser safety and courses available on the subject. Specifically relevant to ablative and nonablative resurfacing is the risk of fire and that of eye safety. Fire is an extremely rare occurrence, but one must be cognizant not to fire an ablative laser on paper products or gauze. In the

operating room, one must be especially careful in the presence of exposed oxygen sources, such as nasal cannulas. Some recommend the use of wet towels around the patient's face to prevent a fire hazard.

Pearl 6

Laser safety is critical to both practitioner and patient.

Eye protection is critical for all personnel and the patient. Laser-specific eyewear is used for the treating practitioner and all people in the treatment room. External or internal metal contact lens-type eye shields must be used on the patient.

Treatment approach

Patient selection, as described previously, is important to achieve desired results. In summary, patient selection depends upon the following factors:

- skin type
- ethnicity
- pathology—rhytides, acne scars, etc.
- recovery time
- finances
- patient expectations.

Pearl 7

Patient selection, as described previously, is important to achieve desired results. In summary, patient selection depends upon their skin type, ethnicity, pathology (rhytides, acne scars, etc.), tolerance for recovery time, and finances.

There are a few absolute contraindications for laser treatment and some areas of caution.

Absolute contraindications

Active infection

This surgical and elective aesthetic procedure should not be performed in the face of active infection. This is true for bacterial, viral, and fungal infections.

Appendageal abnormality

Laser wounds heal in full-field resurfacing from the deep tissues towards the surface from precursor cells in the hair follicles and sebaceous glands, and in fractional resurfacing from those areas and adjacent normal tissue. Patients with abnormalities of the hair follicles and sebaceous glands may have problems with wound healing. Concurrent or recent oral retinoid used to be

considered an absolute contraindication to laser resurfacing but at present time is considered controversial. The data are confusing as to whether fractional resurfacing is safe with oral retinoid use. Most experts agree that with return of sebaceous function at 6 months to 2 years post cessation of oral retinoids it is safe to perform deep full-field resurfacing. Previously x-ray irradiated skin lacks appendageal structures and, as such, should not undergo ablative resurfacing procedures.

Extensive electrolysis may also be an absolute contraindication for deep full-field resurfacing, but fractional or superficial full-field resurfacing should be safe.

Pearl 8

Absolute contraindications for laser resurfacing include infection, appendageal abnormality, deep resurfacing of skin grafts, x-ray-irradiated skin, and extensive electrolysis.

Relative contraindications

Unrealistic expectations are a problem we deal with regularly in plastic surgery and aesthetic dermatology. Laser resurfacing in all its variations can produce some remarkable results but should not be overstated and oversold. Acne scarring especially can be improved dramatically but may require multiple treatments.

Keloid or scarring history

Patients with a history of abnormal scarring may create scars with laser resurfacing. They should be approached with caution, and a test treatment area (test spot) may be helpful.

Regional resurfacing in darker-skinned individuals

Deep full-field resurfacing in darker-skinned patients may create color differences in adjacent areas. Superficial or fractional regional resurfacing is generally considered safe.

Skin grafts

Care must be taken in patients with skin grafts because the appendages mentioned previously are not present in those areas. Resurfacing is routinely used to smooth out the edges; care must be taken with these settings.

Previous deep chemical peel or deep dermabrasion

Caution needs to be taken in patients with previous deep laser or phenol peels or deep dermabrasion because appendages may be damaged and skin may not heal normally.

Previous deep laser resurfacing

Caution also needs to be taken in patients who have had deep full-field resurfacing as appendages may have been damaged. We routinely resurface patients who have had previous deep carbon dioxide or Er:YAG treatments, but we adjust settings appropriately

History of cold sores/herpes simplex 1

Patients with a strong history of cold sores need a modified prophylaxis regimen compared with patients with no history of cold sores. This should start earlier, by 2 to 3 days, and extend longer after healing. Even after being fully epithelialized, recently resurfaced skin seems to have increased susceptibility to viral infection, unlike bacterial infection risk, which seems largely eliminated by full epithelialization.

Pearl 9

Relative contraindications to laser resurfacing include unrealistic expectations, keloid or abnormal scarring history, regional resurfacing in darker-skinned individuals, and previous deep chemical peel, dermabrasion, or laser resurfacing.

Pretreatment and posttreatment regimens

Pretreatment with topical retinoids and bleaching creams is another controversial subject, with proponents on either side of this debate and with data from chemical peel and laser literature being mixed. Our feeling is that, in full-field resurfacing greater than 100 μm in depth, the treated melanocytes are ablated so no benefit to pretreatment is seen. In superficial full-field and fractional resurfacing, pretreatment may be beneficial in preventing hyperpigmentation. Most recommend cessation of these products a few days prior to treatment.

The use of antiviral prophylaxis is important with ablative resurfacing. There is debate in the literature as to when to start antiviral therapy, with some proposing 3 days prior to treatment, whereas others recommend starting on the day of treatment. Most agree that therapy should continue until complete reepithelialization occurs. This time is laser-, patient-, and treatment parameter-dependent. The use of antiviral therapy with fractional treatments is controversial. We recommend its use because the risk of these medications is low.

Prophylactic antibiotic use is often recommended, although we know of no controlled studies of their use. Bacterial infection is extremely rare and is covered in the next section.

After laser treatment, there are a myriad of ways to care for the treated skin. For full-field procedures, most recommend an occlusive ointment or dressing until epithelialization is complete. We find that occlusive dressings, such as Flexzan, work well for carbon dioxide full-field resurfacing but are difficult to

keep on Er:YAG patients, owing to the transudate that occurs following this procedure. Our recommendation is for Aquaphor or petrolatum until epithelialization is complete then a nonocclusive moisturizer, such as Cetaphil lotion. Deep ablative fractional treatments are usually treated with a similar occlusive regimen for 24 to 48 hours, although some may prefer a nonocclusive dressing, owing to the incomplete epidermal removal.

Use of sunblock is mandatory for all laser-resurfacing patients after epithelialization is complete. We also recommend institution of a skin care regimen after epithelialization is complete and the skin has had a chance to "calm down." This may mean a few days for fractional treatments to a few weeks for full-field treatments. There are many good skin care regimens appropriate after laser resurfacing. The combination of 4% hydroquinone and low-strength Retin-A (tretinoin) is still used, although newer regimens with added growth factors are favored by some. The key is to start these regimens slowly to avoid irritation of the skin (see later—dermatitis).

Complications and their treatment

Infection

Infection after laser resurfacing can be viral, bacterial, or fungal. The most well-known complication is due to herpes simplex virus. Many patients have been infected previously and so are carriers. The current recommendation, as outlined previously, is for all patients to be prophylaxed against herpes viral infections. Some patients may avoid taking the antiviral medications, whereas others may experience breakthrough infection (Fig. 7.7). The treatment is early recognition of the infection and treatment with oral antiviral agents. For very severe infections with herpes simplex or zoster, intravenous antiviral medication may be needed.

Pearl 10

Infection after laser resurfacing can be viral, bacterial, or fungal.



FIGURE 7.7 Herpes infection following laser resurfacing. Patient failed to take prescribed antiviral medication and noticed these lesions. Patient was treated with valacyclovir 1000 mg 3 times day and responded without scarring.

Bacterial infection after laser resurfacing using open treatment is uncommon, but with increasing meticillin-resistant *Staphylococcus aureus* (MRSA) there have been patients who have had infection after laser resurfacing. The treatment is administration of broad-spectrum antibiotics with culture of the skin and targeted antibiotic treatment after culture results are obtained.

True fungal infection is rare, but infection with yeast (*Candida albicans*) is common (Fig. 7.8). The patient usually presents with an extremely red face, with a history of having improvement in the healing and suddenly appearing much redder. Treatment is topical antifungal therapy with or without an oral antifungal medication, such as fluconazole.



FIGURE 7.8 Hypopigmentation that developed after laser resurfacing.

Erythema

Erythema after laser resurfacing is a normal part of the inflammatory healing process. It is directly related to the depth of laser resurfacing and to the amount of thermal damage created. Some patients will experience an amount of erythema disproportionate to the treatment. They may be left untreated for the erythema to resolve spontaneously (which it will), or else they may be treated with mild topical corticosteroids, light emitting diode (LED) treatments, IPL treatments, or with a vascular laser such as a pulsed dye laser.

Skin eruptions

Skin eruptions due to acne or milia are common following laser resurfacing. They may be due to overocclusion with topical products or to activation of gland function. Acne may be treated with discontinuation of occlusive agents. If this fails, oral antibiotics and/or acne laser treatment with mid-infrared lasers may be used. Milia are treated by nicking the overlying skin with a small-gauge needle and expressing them with a comedo extractor.

Pearl 11

Skin eruptions due to acne or milia are common following laser resurfacing.

Telangiectasia

Increased appearance of telangiectasia after laser resurfacing is common. This is due to eradication of overlying photodamage and unmasking of the vasculature. Treatment is with a vascular laser.

Dermatitis

Two types of dermatitis are seen following laser resurfacing: irritant and allergic. Irritant dermatitis, as mentioned previously, may be due to the start of topical skin care treatments, such as retinoids, too early or too aggressively. Allergic contact dermatitis is due to true allergy, usually to one of the topical agents, but may also be due to one of the oral antibiotics. Treatment for both conditions is discontinuation of the offending agent and application of a mild topical corticosteroid.

Hypopigmentation

This is a dreaded complication of deep laser resurfacing and has been reported both with carbon dioxide and Er:YAG treatments and with full-field and fractional treatments. It is not uncommon with deep carbon dioxide resurfacing, with some series reporting up to 70% of patients getting hypopigmentation. It is rare with deep Er:YAG full-field resurfacing and very rare with all fractional treatments. There are not many effective treatments, but some have reported improvement with excimer laser therapy. Blending of the noticeable line of demarcation is often helpful.

Hyperpigmentation

Postinflammatory hyperpigmentation (PIH) is a very common problem following laser resurfacing. It is more common in darker skin types and in patients who have had early sun exposure (Fig. 7.9). Prevention as outlined above is key. Treatment is with topical bleaching creams, often combined with retinoids. Failures of this regimen are usually treated with IPL.

Pearl 12

Postinflammatory hyperpigmentation is a very common problem following laser resurfacing.

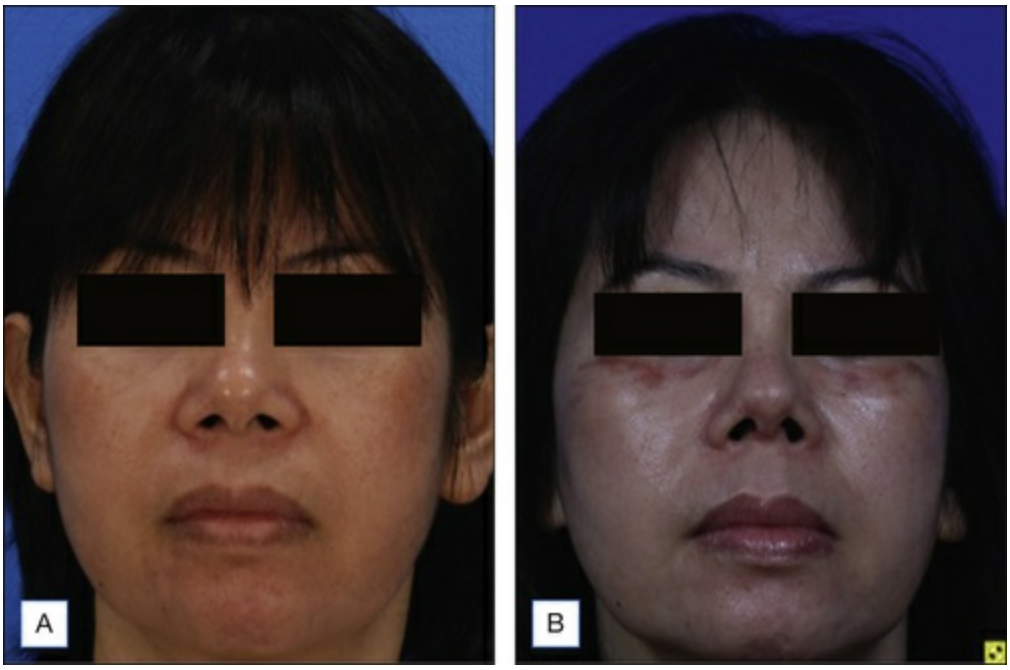


FIGURE 7.9 A 49-year-old Asian woman who developed hyperpigmentation following Er:YAG resurfacing.

Scarring

Scarring after laser resurfacing may occur, owing to overly aggressive full-field or fractional treatment, infection, or even scratching by the patient. Full-field resurfacing is a controlled first- or second-degree burn and anything, such as infection, may convert that controlled second-degree burn into a third-degree burn with resultant scarring. Overly aggressive fractional resurfacing may be due to too deep a treatment or too much density, creating a full-field defect when a fractional treatment was intended. We prefer early treatment of thickened areas that appear to be heading towards scarring with potent topical corticosteroids, such as a pulsed regimen with clobetasol. Intralesional corticosteroids, intralesional 5-fluorouracil, vascular laser or IPL treatment, and fractional lasers have all been used to improve hypertropic scars after laser resurfacing (Fig. 7.10).



FIGURE 7.10 A 64-year-old woman who developed a hypertrophic scar after laser resurfacing: (**A**) before and (**B**) after treatment with intralesional corticosteroids and IPL.

Slow healing

Slow healing has been reported in some cases, with reepithelialization of many months and up to a year. This has led to hypertrophic scarring. This scenario of slow healing may represent an indolent infection. Patients with this scenario should be cultured and potentially biopsied to determine and underlying cause.

Ectropion

Ectropion is caused by laser resurfacing by tightening of the lower eyelid skin in the face of weak lower eyelid canthal support. A snap test or other measurement of lower eyelid laxity is recommended prior to laser resurfacing. Patients with significant laxity are offered either canthal support surgery (rare) or canthal temporary support (temporary tarsorraphy—common).

Synechia

This is caused by healing of two epidermal surfaces and appears as a line (usually in the lower eyelid). If untreated this may lead to cyst formation. Treatment is to manually stretch the edges of the synechia until the line opens.

Check online videos (Video 7.1 - ▶7.3).

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8

Nonsurgical body contouring

Andrew A. Nelson, Andrew Breithaupt



Summary and Key Features

- Given the epidemic rise of obesity and the obsession with losing weight and improving our appearance, the treatment of fat and cellulite is a common cosmetic issue.
- Fat and cellulite are distinct entities. Cellulite is best considered a hormonally based structural phenomenon of adipocytes and fibrous septae, whereas excess fat is an overabundance of normal adipocytes.
- The treatment options for excess fat and cellulite are different—a treatment that improves one may have no discernible impact on the other.
- Noninvasive body contouring is a rapidly expanding cosmetic field, with many new technologies recently developed and promising new technologies expected in the near future.
- Topical agents, such as retinoids and methylxanthines, have theoretical benefits on the appearance of fat and cellulite, though objective clinical improvements are limited.
- Injectable therapies, including mesotherapy and injection lipolysis, are also options.
- Physical massage of the affected areas may improve the appearance of fat and cellulite by modulating blood and lymphatic flow.
- Radiofrequency devices use alternating current to generate ionic flow and

localized heat in adipocytes, moderately improving the appearance of fat and cellulite.

- Focused ultrasound also specifically targets adipocytes by using pressure waves to damage the cellular membrane, ultimately improving the appearance and thickness of the fat layer.

- Several laser devices using near-infrared wavelengths, in combination with physical manipulation, have been developed to improve the appearance of fat and cellulite by stimulating dermal collagen formation.

- An adipocyte-specific laser has been developed which selectively heats the adipocytes, thereby leading to apoptosis and clinical reduction in fat volume.

- Cryolipolysis is a therapy by which controlled cold exposure (heat extraction) is used to selectively damage adipocytes, cause apoptosis, and gradually improve the appearance and thickness of the fat layer over several months following the treatment.

Introduction

Obesity is an unfortunate epidemic in the United States, and weight loss remains a challenging goal for many people. Not only does excess fat present cosmetic challenges to our patients, but it is increasingly obvious that there are also associated significant and dangerous medical effects.

In this section, we will focus on noninvasive techniques to improve the appearance of fat and cellulite, the benefits of these technologies, and their limitations. The devices and techniques reviewed herein should be thought of not as ways to achieve weight loss but rather, modest body contouring.

These body-contouring treatments are one of the most rapidly expanding areas in medicine and our general culture. According to the American Society for Dermatologic Surgery (ASDS), 230,000 body sculpting procedures were performed in 2015, an increase of 11% from 2014. Although many of the technologies are relatively new, their potential utility will ultimately need to be determined by well-done randomized scientific studies.

Any discussion of treatment of excess fat must begin with liposuction and lasers used in conjunction with liposuction; however, this technique is covered extensively in Hanke and Sattler's Liposuction in this series and will not be reviewed here. Although liposuction continues to remain the true gold standard for treating excess fat, it also requires an invasive procedure with associated discomfort, bruising, and downtime. The last five years has witnessed many new technologies that have been developed to treat excess adipose tissue through noninvasive techniques. These noninvasive devices use a multitude of techniques to improve the appearance of excess adipose tissue, including a reduction in the overall volume of fat, improvement in the appearance of cellulite, and skin tightening.

Fat versus cellulite

Prior to discussing therapeutic options, it is necessary to first differentiate fat and cellulite. Excess fat and obesity are an epidemic, mainly resulting from poor dietary and exercise habits. Fat represents a deposition of excess, but structurally normal, adipose tissue. In contrast, cellulite is best considered a hormonally based structural phenomenon of adipose tissue. It is seen almost ubiquitously in post-pubescent females and rarely in men. As a result of these differences, the techniques and technology that effectively treat excess fat may not have any effect on the appearance of cellulite, and vice versa.

Pearl 1

Excess fat is due to accumulation of normal adipocytes, whereas cellulite is best thought of as a hormonally based structural phenomenon of adipocytes and fat septae. As a result the evaluation and treatment of these conditions are often divergent.

It is thought that hormones likely play a significant role in the formation of cellulite. Estrogens stimulate lipogenesis and inhibit lipolysis, resulting in adipocyte hypertrophy. Cellulite is typically rare in pre-pubertal females and males of any age but is extremely common in post-pubertal females. In fact, it has been suggested that cellulite is best considered a secondary sexual characteristic of females. It has also been proposed that cellulite develops in at-risk areas, due to less effective lymphatic and vascular circulation. Exactly how these differences ultimately cause the structural abnormalities of adipose tissue that result in the appearance of cellulite has not been fully elucidated.

Ultrasound and magnetic resonance imaging (MRI) studies have demonstrated the significant structural alterations between male adipose tissue and female cellulite structure. In male adipose tissue the fibrous septae of the adipose tissue are arranged in an overlapping crisscross pattern. This theoretically provides greater strength to the overall scaffolding of the adipose tissue and prevents herniation of fat cells. In contrast, cellulite has fibrous septae that are arranged parallel to each other and perpendicular to the skin surface (Fig. 8.1). This structure is weaker and allows for the focal herniation of adipose tissue. It is this focal herniation that is thought to cause the classic undulating, lumpy, "cottage cheese" appearance of cellulite. MRI has demonstrated that women with cellulite do indeed have fibrous septae that are oriented in parallel to each other, although these septae may actually be more similar to pillar-like columns (Figs. 8.2 and 8.3). In addition to this structural difference, MRI, ultrasound, and biopsies have also demonstrated that women with cellulite typically have an undulating, lumpy interface between the adipose tissue and the dermis, known as *papillae adiposae*. This interface also likely contributes to the appearance of cellulite.

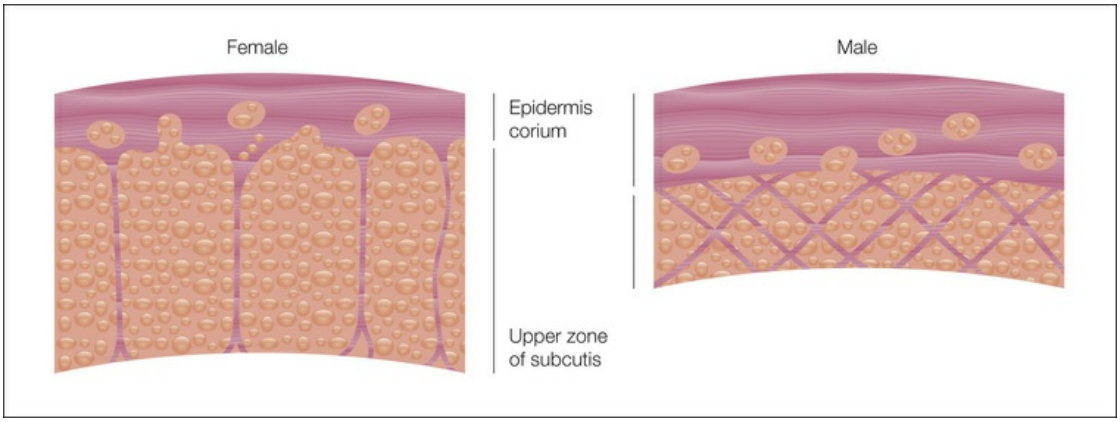


FIGURE 8.1 Orientation of subcutaneous fibers extending from dermis to fascia in males and females. Reprinted by permission of Blackwell from Nurnberger F, Muller G. So-called cellulite: an invented disease. *J Dermatol Surg Oncol*. 1978;4:221.

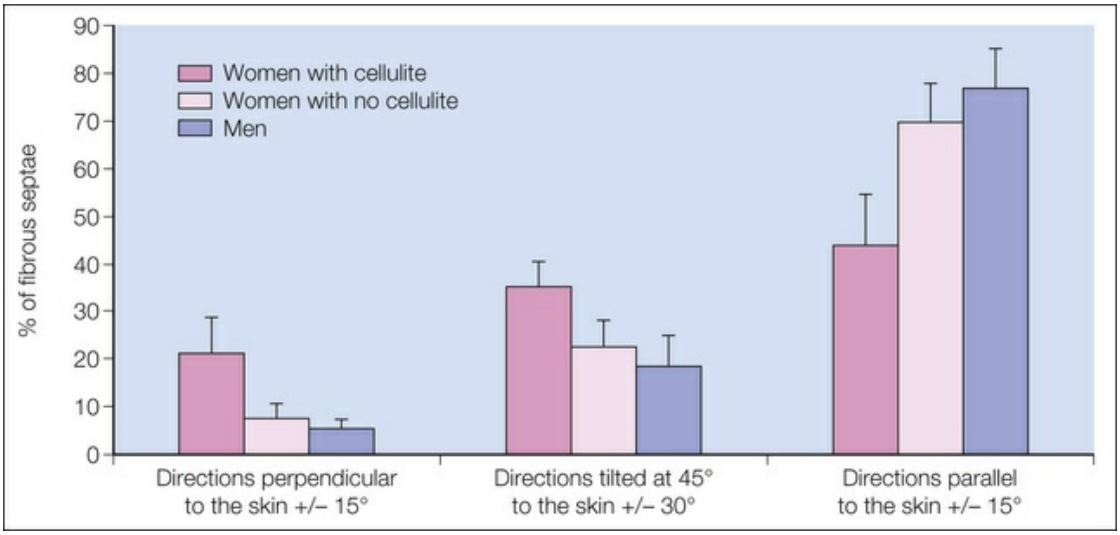


FIGURE 8.2 Structured patterns of the fibrous septae network according to gender and presence of cellulite. Our quantitative findings give more evidence about the heterogeneity in the directions of the septae and highly suggest that modeling the three-dimensional (3D) architecture of fibrous septae as a perpendicular pattern in women but tilted at 45 degrees in men would be an oversimplification. Reprinted by permission of Blackwell from Querleux B, Cornillon C, Jolivet O, Bittoun J. Anatomy and physiology of subcutaneous adipose tissue by in vivo magnetic resonance imaging and spectroscopy: relationships with sex and presence of cellulite. *Skin Res Technol*. 2002;8:118–124.

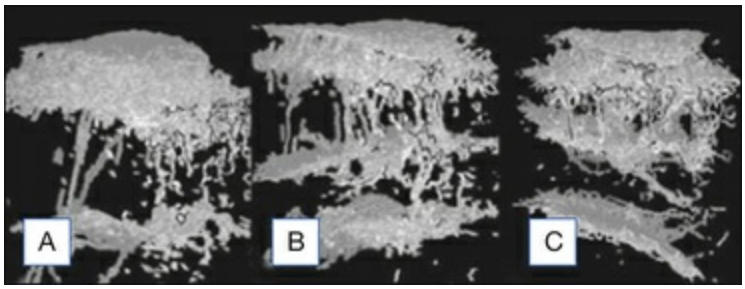


FIGURE 8.3 Visualization of the three-dimensional (3D) architecture of fibrous septae in subcutaneous adipose tissue: (**A**) woman with cellulite, (**B**) normal woman, and (**C**) man. Reprinted by permission of Blackwell from Querleux B, Cornillon C, Jolivet O, Bittoun J. Anatomy and physiology of subcutaneous adipose tissue by in vivo magnetic resonance imaging and spectroscopy: relationships with sex and presence of cellulite. *Skin Res Technol*. 2002;8:118–124.

It is less well established whether excess adipose tissue contributes to the appearance of cellulite. There are many thin females who have the appearance of cellulite on their bodies, whereas some heavier females may display only a subtle appearance of any cellulite. It is likely that excess adipose tissue may predispose or exacerbate cellulite, but it is less likely that excess adipose tissue alone is a driving factor. We believe that excess fatty tissue and cellulite should be considered as two distinct entities and that they should be evaluated and treated as such.

Evaluation of fatty tissue and cellulite

Body mass index (BMI), a person's weight in kilograms divided by the square of their height in meters, remains the classic method for determining obesity. However, this may be an oversimplification because it does not necessarily take into account the patient's mixture of muscle and adipose tissue or their overall body type. Furthermore, many patients presenting for noninvasive body sculpting may be in very good shape overall with only a few small problem areas, such as the thighs or flanks. Although BMI may be a useful tool for defining obesity in large populations, we do not find it particularly useful in our practice. More commonly, we use such measurements as thigh circumference, waist circumference, skinfold thickness, visual assessment, and photographic comparisons pre- and post-procedure in our practice because these more typically reflect the patient's ultimate clinical presentation and outcome. It is important to note that there can be a great deal of variability in these measurements if not performed properly. For example, if the waist circumference is not measured at precisely the same location or in the exact same manner on a patient there will not be consistency in the measurements and the treatment effect will be difficult to determine. Lighting of before and after photographs can also greatly impact the appearance of the images, leading to over exaggeration or under appreciation of a treatment effect. It is therefore essential that staff be properly trained to perform these measurements and photographs reliably and consistently.

Pearl 2

BMI is a simple tool to assess overall body habitus. However, BMI is often not the best method to assess localized areas of fat excess and is not often used in our clinical assessments. Furthermore, obese patients (BMI > 30) are often not good candidates for noninvasive body contouring and may require diet, bariatric, or other surgical interventions.

Cellulite can similarly be assessed with various measurements and definitions. Typically, direct observation with side lighting is the simplest and most effective assessment. Based upon these observations, a relatively simple scoring system for the appearance of cellulite has been described (Table 8.1).

Table 8.1

Cellulite classification

Grade I	No or minimal skin irregularity upon standing, pinch test, or muscle contraction
Grade II	No or minimal skin irregularity upon standing. Dimpling becomes apparent by pinching or muscle contraction
Grade III	Classic skin dimpling at rest with palpable, small subcutaneous nodularities
Grade IV	More severe puckering and nodularity

More recently, technologies such as ultrasound, MRI, and electrical conductivity have been used to assess adipose tissue and cellulite. These technologies are often used in clinical trials to assess the potential efficacy of a novel therapeutic option. However, they are typically not necessary in the evaluation and management of patients in general practice.

Therapeutic options

There are many different technologies and techniques for noninvasive body sculpting. Options include topical creams, injectable agents, physical manipulation, lasers and light sources, and cryolipolysis. The best option for your patient is dependent on their clinical presentation, treatment goal, and most importantly, their preferences. It is important to emphasize that none of these treatments provides more than a modest, local contouring benefit in most instances.

Topical creams

A simple trip to any cosmetic aisle or beauty store demonstrates that there are numerous topical creams that purport to melt away fat and cellulite. Generally speaking, the active ingredients in these products are thought to stimulate improved circulation, improve lymphatic drainage, or cause lipolysis to improve the appearance of fat and cellulite. The most commonly used ingredients include caffeine, aminophylline, and retinoids. Although there are a

few limited studies on these creams, many agents have little or no hard evidence to support their claims and the ability of the active ingredients to penetrate to the necessary depth is a matter of significant debate.

Pearl 3

Many topical creams are advertised to improve the appearance of fat and cellulite. In our view, these claims should be regarded skeptically.

Topical retinol compounds have long been a mainstay in cosmetic regimens, owing to their ability to stimulate neocollagenesis. Topical retinoids could theoretically improve the appearance of cellulite by increasing collagen deposition and promoting glycosaminoglycan synthesis, thereby resulting in stronger and denser fibrous septae. In clinical studies the results have been modest. Kligman et al. conducted a double-blind study of 20 patients who applied topical retinol twice daily for 6 months and demonstrated a clinical improvement. A further study of 15 patients by Pierard-Franchimont et al. demonstrated a phenotypic shift of connective tissue cells but no visible improvement in overt cellulite appearance following 6 months of application of topical retinol. Thus, although topical retinoids may be of benefit in improving the appearance of fat and cellulite, this benefit is likely modest at best.

Methylxanthines, such as aminophylline, have also been reported to be effective in treating cellulite. These agents act as phosphodiesterase inhibitors, which, when applied, result in an increase in cyclic adenosine monophosphate (cAMP) levels. This increase in cAMP could theoretically activate hormone-sensitive lipase and thereby stimulate lipolysis in the treated areas. Studies have shown conflicting results in their effectiveness to reduce fat and cellulite. Most recently micronized phospholipid carriers have been developed to increase the penetration of methylxanthines. Initial studies with these compounds have shown promising results but await further verification.

Numerous herbal therapies have also been reported to be effective in treating fat and cellulite (Table 8.2). Many of these herbal supplements have not undergone rigorous testing to determine their efficacy, and there is therefore little or no scientific evidence to support their use.

Table 8.2

Herbal treatments for cellulite

Herbal name	Concentration (%)	Parts of the plant	Main constituents	Mechanism of action
Bladderwrack	1	Whole dried thallus	—	Stimulates vascular flow
Butcher's broom	1–3	Rhizome and flowering tops	Saponins, ruscogenin, and neororuscogenin	Improves microcirculation
Ginkgo biloba	1–3	—	—	Improves microcirculation
Cynara scolymus or	—	Leaves,	Enzymes, cynarin,	Reduces edema and promotes

artichoke		flower heads, and roots	ascorbic acid, caffeoylquinine acid derivatives, and flavonoids	diuresis
Common ivy	2	Dried leaves, stems	Saponins (especially hederin)	Improves venous and lymphatic drainage and reduces edema
Ground ivy	2	—	Flavonoids, triterpenoids, and phenolic acids	Increases microvascular flow
Indian or horse chestnut	1–3	Seeds, shells	Triterpenoid saponins and flavones, coumarins and tannins	Reduces lysosomic enzyme activity and capillary permeability
Sweet clover	2–5	Flowers and leaves	Coumarin	Reduces lymphatic edema and capillary permeability
Centella asiatica	2–5	Leaves and roots	Asiaticoside, madecassic acid, asiatic acid	Antiinflammatory and potent healing effects
Red grapes	2–7	—	Tannins, procyanidins	Contains antioxidants that decrease lipid peroxidation and increase permeability of lymphatic and microarterial vessels
Corynanthe yohimbe, *Pausinystalia yohimbe*, and *Rauwolfia serpentina*	—	Leaves, shells, roots	Yohimbe	Stimulates metabolism of fat cells
Papaya	2–5	Fruits, leaves	Papain and bromelain (proteolytic enzymes)	Antiinflammatory effects, decreases edema

Injectable agents

Many different agents have been injected with the goal of dissolving excess adipose tissue and cellulite. Mesotherapy, or intradermotherapy, is performed by the direct injection of pharmacologic agents into the dermal–subcutaneous junction of the skin. This procedure is purported to work by acting directly on the adipocyte to promote lipolysis or adipolysis and thereby improve the appearance of fat and cellulite.

A closely related but separate technique is known as injectable lipolysis, in which detergents, such as bile salts, are injected into the subcutis to chemically ablate adipose tissue. In 2015 Kybella (deoxycholic acid, Allergan, Irvine, California) became the first US Food and Drug Administration (FDA)-approved injectable fat-reduction agent. It is indicated for the treatment of adults with moderate-to-severe fat in the submental neck. The product is injected into the preplatysmal fat in 0.2-mL aliquots spaced 1 cm apart in a grid-like pattern. In clinical trials the average dose was 4 to 6 mL per treatment session. In these trials 28%, 43%, and 55% of treated patients had a ≥1-grade composite improvement after two, three, and four treatment sessions, respectively. The role of deoxycholic acid and other injectable agents for off-label body contouring remains to be determined as their use in clinical practice expands.

Physical manipulation

Endermologie (LPG Systems, Valence, France) is an FDA-cleared device that

massages and kneads the skin to improve the appearance of cellulite. The device uses two rollers, as well as positive and negative pressure, to manipulate the patient's skin. The technique is thought to stimulate blood and lymphatic flow, thereby altering the architecture of the fat and improving the appearance of cellulite. In clinical studies, modest clinical improvements have been observed. A study by Gulec of 33 women who were treated with Endermologie for 15 sessions demonstrated a statistically significant improvement in the appearance of cellulite, as assessed by a visual scale; however, few of the patients (5 of the 33) actually demonstrated clinical improvement. A study by Collis et al. compared twice-weekly treatment with Endermologie with a combination treatment of aminophylline cream and Endermologie. The authors concluded that Endermologie is not an effective treatment of cellulite, although 10 out of 35 patients with Endermologie-treated legs reported that their cellulite appearance improved. In summary, Endermologie may result in modest improvements in the appearance of fat and cellulite in some patients, although it likely requires continuing treatments to maintain any improvement. Home therapy units, such as Well Box, are available to facilitate ongoing convenient treatment and may be of benefit to patients.

Pearl 4

Physical manipulation, such as Endermologie, may result in modest, temporary improvement in the appearance of cellulite, but the results are transient and often require ongoing treatments. At-home units may be a convenient and effective option for patients.

Subcision is a relatively simple technique to attempt to improve the appearance of cellulite. A special notched catheter needle is placed into the subcutis of the affected area. The catheter is then physically manipulated by pushing and pulling to break up the fibrous stranding and tethers that are thought to be responsible for the appearance of cellulite. By destroying these fascial tethers, the appearance of cellulite is thought to improve. Side effects, such as ecchymosis and edema, are common. The clinical utility of this method likely varies depending on the skill of the surgeon, and its clinical utility remains to be fully determined.

In 2015 Cellfina (Merz, Frankfurt, Germany) became FDA cleared for long-term (>2 years) improvement in the appearance of cellulite on the buttocks and thighs. The device uses a vacuum-assisted approach to lyse the fibrous bands underlying cellulite. Using a motorized module, a small blade is inserted into individual dimples under local anesthesia to subcise the connective tissue band and release the dimple associated with the cellulite. In the Cellfina Registry Under Investigation for Safety and Efficacy (CRUISE) study, a total of 53 female patients underwent a single Cellfina treatment. Eighty-one percent of patients self-reported improvement in the appearance of cellulite on buttocks and thighs, with 44.4% of patients reporting improvement and 30.5% reporting much improvement. The average Clinician Global Aesthetic Improvement

Score was 2.05, corresponding to much improved. The most common side effects were bleeding, blanching, fluid accumulation, ecchymosis, and induration. Cellfina represents a promising new technology for long-term improvement in the appearance of cellulite.

Liposuction remains the gold standard treatment for physical removal of excess adipose tissue. A full discussion of liposuction techniques is beyond the scope of this chapter. However, it is important to note that liposuction's role in the treatment of cellulite is not well established. There are reports of liposuction improving, as well as worsening, the appearance of cellulite. Given the architectural component of cellulite physiology, it is not unexpected that bulk fat removal alone would not improve its appearance.

Pearl 5

Liposuction is the gold standard for large-volume fat removal but is much less reliable for small, localized fat excess. Liposuction is best in patients with greater than 1 inch (25 mm) of pinched skin and fat on exam. Liposuction is also less reliable for the treatment of cellulite.

Case Study 1

A female patient presents to discuss noninvasive fat treatment options. She is 35 years old, weighs 185 pounds (84 kg) and is 5′4″ (1.63 m) tall. She has also developed early-onset type II diabetes. She has previously tried to lose weight with diet and exercise but has been unsuccessful. She was recently evaluated by her PCP, who encouraged her to lose weight to improve her diabetes and overall health. She presents to your office because she would like a procedure to treat her excess adipose tissue.

This patient has a common misconception that noninvasive fat treatment can substitute for large-scale weight loss. This patient's BMI is 31.8, which defines her as obese. Furthermore, she already has a medical comorbidity, diabetes, associated with her obesity. This patient absolutely needs help losing weight and improving her medical health, particularly because she has tried and failed previous weight loss strategies. She should be referred to a bariatric weight loss program to help her to achieve her goals of weight loss.

If she is interested in a procedure to help to improve her chances of successfully losing weight, this patient may be a good candidate for laparoscopic banding, partial gastrectomy, or gastric bypass. After the patient has lost weight and is closer to her ideal weight, if she continues to have focal trouble spots of excess fat, she may benefit from a noninvasive body-sculpting procedure at that time.

Radiofrequency devices

Radiofrequency (RF) devices pass sinusoidal, alternating current (AC) through tissue to generate heat. The AC causes ionic flow in the treatment tissue, thereby creating heat from molecular friction. In essence, the tissue itself is the

source of the heat, rather than the actual device. As a result, RF is thought to cause localized heating of a targeted tissue mass, while limiting the potential for collateral spread of energy, neuromuscular reaction, or electrolysis. Adipose tissue has high tissue resistance and a relatively low heat transfer coefficient; as a result, adipose tissue can be readily heated and the heat will be predominantly confined to the adipocytes. Many RF devices have been advertised to improve the appearance of fat and cellulite.

The VelaSmooth and VelaShape (Syneron Candela, Irvine, California) devices combine physical manipulation (massage and suction), with bipolar RF energy and infrared light (700 to 2000 nm) to treat excess fat and cellulite. It has been proposed that these devices improve fat and cellulite by heating the subcutaneous tissue and fat, thereby causing increased localized blood flow and lipolysis. In a randomized clinical study by Nootheti et al. comparing the VelaSmooth device with another laser device for cellulite (TriActive, Cynosure Inc., Westford, Massachusetts), patients were treated twice weekly for 6 weeks. Following the treatments, patients were observed to have an improvement in the upper and lower thigh circumference, as well as in the appearance of cellulite (Figs. 8.4 and 8.5). Seventy-five percent of patients were observed to have an improvement, when comparing pre- and post-treatment photographs, but the results were modest. There were no statistically significant differences in the efficacies of the two devices. Bruising can occur following treatment with the VelaSmooth device and was more common with this device than the Triactive device (Fig. 8.6).



FIGURE 8.4 A 47-year-old woman (**A**) before and (**B**) after six treatments with the VelaShape device. Photos courtesy of Neil S. Sadick, MD.

Reprinted with permission from Sadick NS. VelaSmooth and VelaShape. In Goldman MP, Hexsel D, eds. *Cellulite: Pathophysiology and Treatment.* 2nd ed. New York, NY: Informa Healthcare; 2010: 108–114.

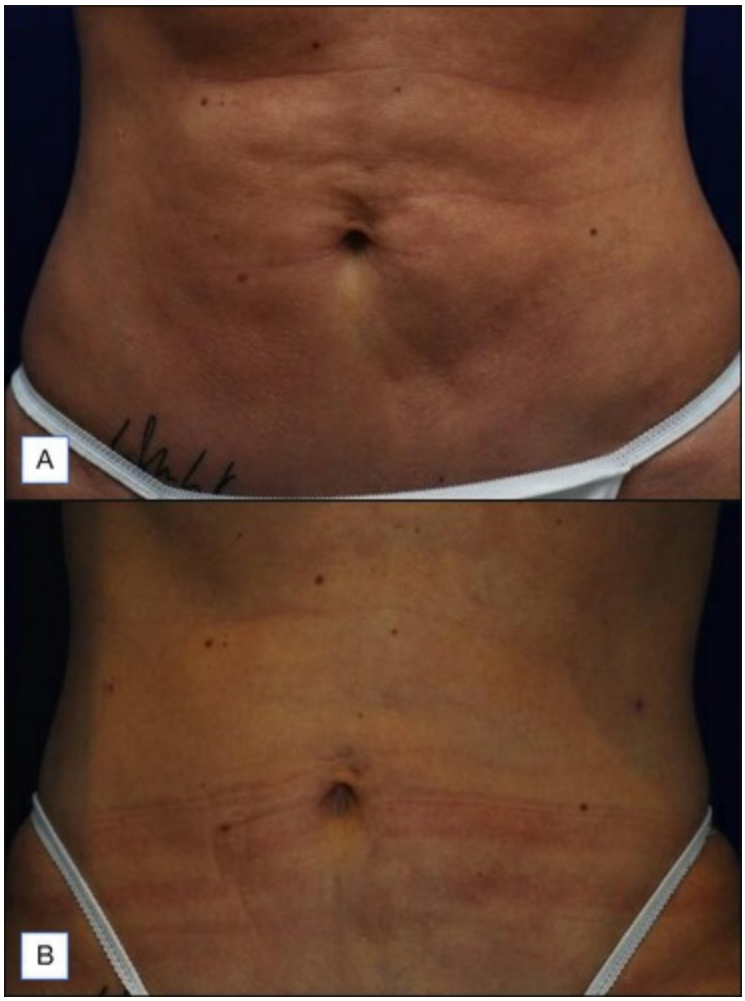


FIGURE 8.5 A 37-year-old woman (**A**) before and (**B**) after seven treatments with the VelaShape device. Photographs courtesy of Neil S. Sadick, MD. Reprinted with permission from Sadick NS. VelaSmooth and VelaShape. In Goldman MP, Hexsel D, eds. *Cellulite: Pathophysiology and Treatment.* 2nd ed. New York, NY: Informa Healthcare; 2010: 108–114.

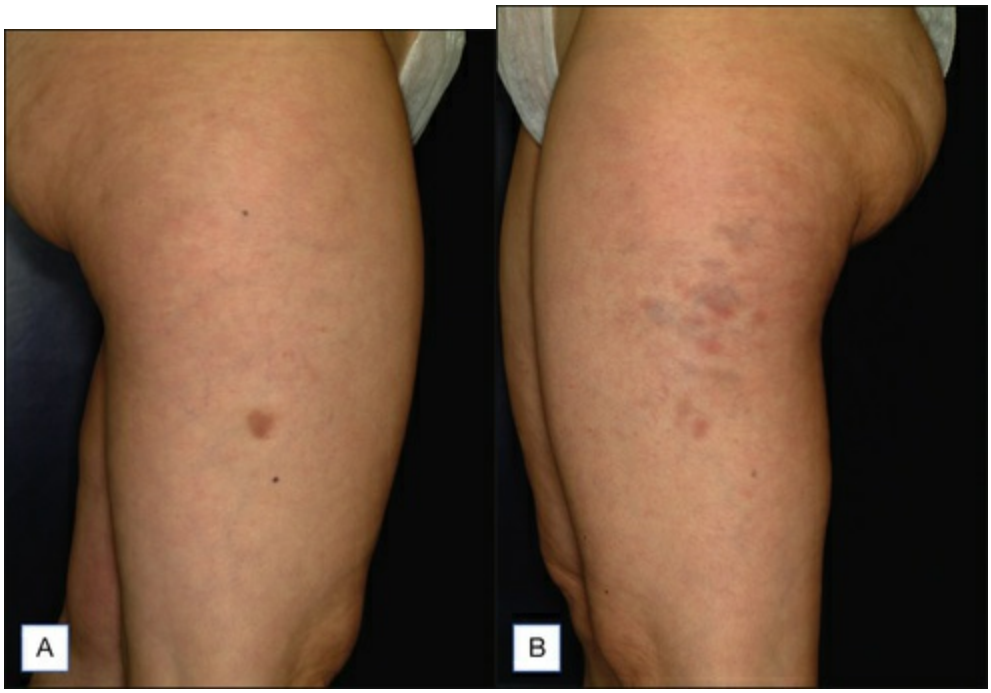


FIGURE 8.6 Purpura after treatment with (**A**) Triactive and (**B**) Velasmooth. Reproduced with permission from: Nootheti PK, Magpantay A, Yosowitz G, Calderon S, Goldman MP. A single center, randomized, comparative, prospective clinical study to determine the efficacy of the Velasmooth system versus the Triactive system for the treatment of cellulite. *Lasers Surg Med.* 2006;38:908–912.

The BodyFX (InMode, Inc., Yokneam, Israel) is an FDA-cleared device that uses a suction-coupled, bipolar RF configuration, with a built-in infrared skin surface temperature sensor to heat deep dermis and adipocytes. In addition, the device also uses trains of high-amplitude, high-voltage, ultra-short (nanosecond) pulse duration RF pulses into the preheated adipose tissue, causing irreversible electroporation (IRE) of the adipocyte cell membrane. This starts the cascade of apoptosis, ultimately resulting in permanent, programmed cell death of the adipocytes. In a clinical study of 21 patients by Boisnic et al., significant reductions in abdominal circumference (113.4 to 110.7 cm), reduction of subcutaneous adipose tissue thickness (40.5 to 38.5 mm), and reduction in adipose tissue weight were observed following a series of six treatments with the BodyFX. Importantly, histologic changes were observed, including adipocytes with decreased size and withered shape, increased levels of adipocyte apoptosis, increased collagen synthesis, and compaction and reorganization of the dermis.

Pearl 6

Bruising is a common side effect of laser and light source treatments for fat. Most commonly, the bruising is related to the vacuum pressure and physical manipulation of the device rather than the actual laser.

Unipolar, volumetric RF devices with more diffuse, deep heating have also

been advocated for the treatment of fat and cellulite. Goldberg et al. treated 30 patients with a unipolar RF device (Accent, Alma Lasers US, Buffalo Grove, Illinois) every other week for a total of six treatment sessions. A decrease in mean leg circumference of 2.45 cm was observed, although the study was limited due to a lack of comparative controls. In general, circumference is not a good end point to assess cellulite improvement. Histologic specimens did demonstrate dermal fibrosis that could explain the clinical improvement, although the results were limited. Further clinical studies are necessary to establish the potential role for these RF devices.

Ultrasound devices

Patients are typically accustomed to the diagnostic utility of ultrasound imaging devices. Focused ultrasound devices have also been developed to treat the subcutis and adipocytes. Although these devices have shown promising initial results, long-term clinical studies are lacking.

The Liposonix device (Solta Medical, Valeant Pharmaceuticals, Hayward, California) is FDA cleared for noninvasive waist circumference reduction. A study by Jewell et al. of the Liposonix device documented significant improvement following a single treatment session. One hundred and eighty patients were randomized to either a sham treatment or one of two doses of high-intensity focused ultrasound. Twelve weeks after the ultrasound treatment, the patients treated with the higher dose had achieved a statistically significant improvement in waist circumference compared with the sham group (−2.44 cm vs. −1.43 cm). Patients were observed to have "improved" or "much improved" outcomes as assessed by physicians, and patients were satisfied with their treatments. The procedure is often painful, and bruising and edema develop after treatments. However, no significant laboratory abnormalities were observed following treatment, including lipid profiles, markers of inflammation, coagulation, liver or renal function, hematologic assessments, or blood chemistry.

The Ultrashape System (Syneron Candela, Irvine, California) received FDA approval in 2014 for the treatment of excess adipose tissue. A prospective, nonrandomized, controlled trial of 164 patients was conducted by Teitelbaum et al. to determine the efficacy of the device; 137 patients underwent one ultrasound treatment to the abdomen, thighs, or flanks; 12 weeks later, mean circumference reductions of 2.3 cm (abdomen), 1.8 cm (thighs), and 1.6 cm (flanks) were observed. The majority (77%) of the improvement in circumference was noted to occur within the first 14 days following the treatment.

Ultrasound technologies represent a new and evolving area within the field of noninvasive fat treatment. Initially, many of the ultrasound technologies were incorporated into liposuction treatments, known as ultrasound-assisted liposuction (UAL). However, more recently, high-intensity focused ultrasound is being developed as a stand-alone, noninvasive treatment for improving the appearance of fat and cellulite. These devices require further clinical study to

determine their long-term efficacy and safety profile. Nevertheless, they represent an exciting and promising opportunity within this field.

Lasers and light sources

Many different light sources and lasers have been advocated as therapeutic options for fat and cellulite. Many are incorporated into liposuction procedures, known as laser-assisted liposuction (LAL); however, these devices still require invasive liposuction. Other devices have been marketed as being effective, noninvasive therapies for fat and cellulite, although definitive objective evidence of their efficacy may be lacking. Several devices that are advertised to improve fat and cellulite do not actually affect the adipocytes themselves but rather target the dermis in an attempt to stimulate collagen formation/remodeling. Devices with wavelengths in the near-infrared region, as well as intense pulsed-light (IPL) sources, fall into this category.

The TriActive device combines deep tissue massage and suction (similar to Endermologie), with contact cooling and a low-intensity diode laser (808 nm). The device purports to increase lymphatic drainage, improve blood flow, and simultaneously tighten skin in the treated areas, which is thought to improve the appearance of cellulite. Patients typically are treated with the device twice weekly, with a progressive improvement following the treatments. In clinical studies, patients were noted to achieve improvement in the appearance of cellulite, as well as objective improvement in hip and thigh circumferences. Subjective improvement included reduction in the appearance of skin dimpling, improvement in the overall contour of the limb, and improvement in overall skin texture (Fig. 8.7). The treatments were well tolerated, although many patients (approximately 20%) developed mild bruising.

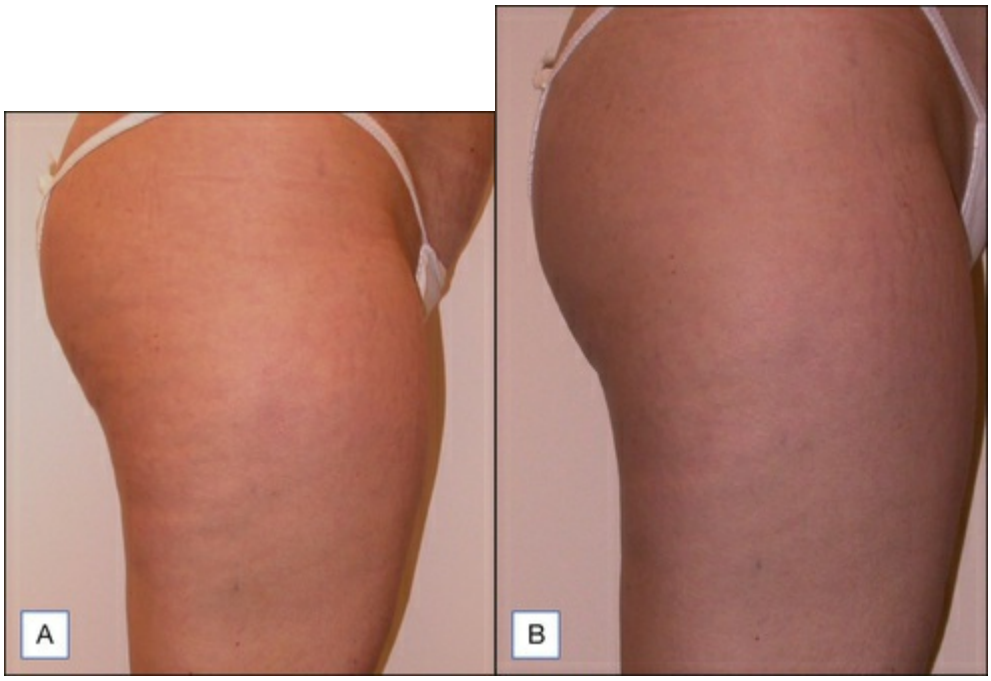


FIGURE 8.7 Cellulite treatment with Triactive: subject (**A**) before and (**B**) following 10 treatments. Reproduced with permission from: Boyce S, Pabby A, Chuchaltkaren P, Brazzini B, Goldman MP. Clinical evaluation of a device for the treatment of cellulite: Triactive. *Am J Cosmet Surg*. 2005;22:233–237.

The SmoothShapes device (Eleme Medical, Merrimack, New Hampshire) combines two different wavelengths with a massage system similar to Endermologie. The 915-nm diode wavelength is reported to cause liquefaction of the fat, and the 650-nm wavelength is thought to improve fat membrane permeability, thereby allowing the adipocytes to be mobilized to the interstitium. Multiple passes with the device are typically performed during a treatment session, with two to three sessions being performed each week for best results. In clinical studies by Lach and Kulick the SmoothShapes device resulted in reduction of the thickness of the subcutaneous fat pad, as assessed by MRI. The device was well tolerated with no significant associated adverse events.

The VelaSmooth and VelaShape devices combine physical manipulation with RF energy, as well as infrared energy, to facilitate a multimodality approach to fat and cellulite treatment. The efficacy of these devices was previously discussed in the above section on RF. In the future, more devices may approach fat and cellulite treatment through this multimodality approach in an effort to achieve greater efficacy.

Fat-specific laser

Sculpsure (Cynosure Inc., Westford, Massachusetts) is an FDA-cleared device for noninvasive lipolysis of the flanks and abdomen. In comparison with the laser devices discussed previously, Sculpsure uses a 1060-nm diode laser to specifically target adipocytes. This wavelength of light effectively heats the adipocytes with minimal heating of the dermis and surrounding tissue. The device cycles through heating and cooling phases during the 25 minutes of treatment to heat and maintain the adipocytes to a temperature between 42°C and 47°C. This heating of the adipocytes causes them to undergo heat-stimulated apoptosis, and the adipocytes are then cleared by the body's lymphatic system over the 6 to 12 weeks. In initial clinical reports, fat volume (as measured by MRI) was reduced by an average of 24% following a single treatment with Sculpsure. Although this is an exciting new technology, long-term clinical trials will be needed to determine its efficacy.

Cryolipolysis

CoolSculpting (Zeltiq Aesthetics, Pleasanton, California) is an FDA-cleared device for noninvasive fat reduction; it uses cryolipolysis technology to selectively cool fat, extracting energy, and ultimately causing apoptosis. The treatment consists of applying a treatment applicator to the patient's desired treatment area, typically the flank (“love handle”), the back (“back fat pads”), or the abdomen (“muffin top”). A variety of hand pieces have been introduced to

treat varying-size fat pockets, including a small applicator designed to treat anterior neck fat. A moderate vacuum is then created by the device, drawing the tissue between the treatment plates and clamping down on local cutaneous blood flow to increase the efficiency of cooling. The treatment cycle ranges from 35 to 75 minutes, at the conclusion of which the skin appears cool, firm, and erythematous. The tissue is typically molded into the shape of the treatment applicator. At the conclusion of the treatment, the physician massages the area gently to break up any crystallized adipocytes (Video 8.1). Over the next several weeks to months, the adipocytes are mobilized and eliminated by the body.

Case study 2

A 53-year-old female, who is 5′6″ (1.68 m) tall and weighs 145 pounds (66 kg), presents for treatment of small pockets of excess fat around her abdomen. She would like to discuss noninvasive treatment options because she is concerned about the risks of invasive surgery.

This patient's BMI is 23.4, which is within the normal range. She does have localized pockets of excess adipose tissue below the umbilicus, without substantial skin redundancy. This patient could be a good candidate for localized, tumescent liposuction, if she desired. However, she states she does not want an invasive procedure. After discussing options, she elects to have the area treated with CoolSculpting. The proposed treatment area is marked (a separate, but representative patient is shown in Fig. 8.8A). Due to the size, two applications in the same treatment session will be necessary to treat the complete area, each marked with an X (see Fig. 8.8B). A pinch test is performed to ensure that the area can be effectively elevated in the device (see Fig. 8.8C). The patient undergoes treatment with no adverse effects.



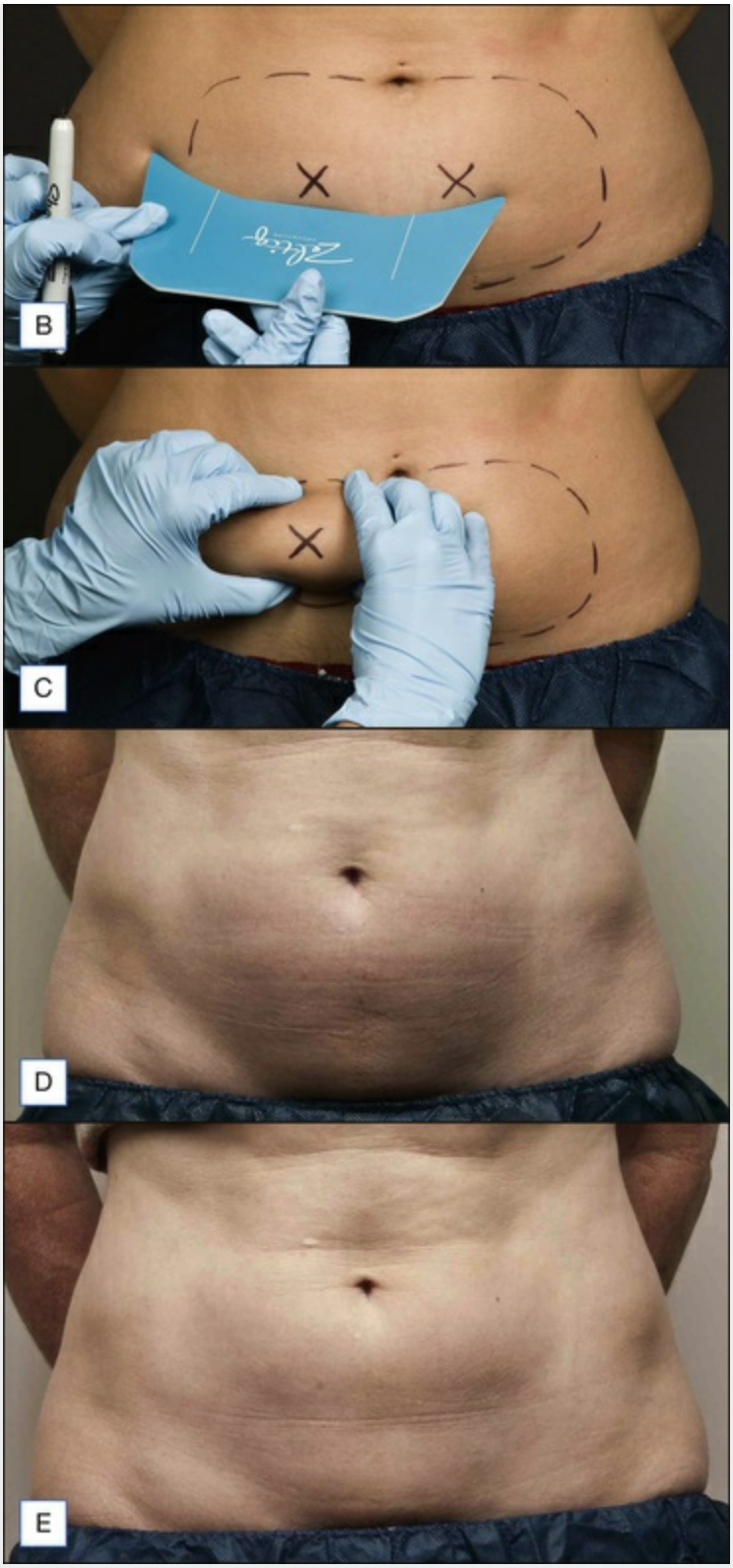


FIGURE 8.8 A female patient presents for treatment of a localized accumulation of excess adipose tissue below the umbilicus. **A,** The treatment area is outlined by the treating physician. **B,** The treating physician then compares the size of the treatment applicator with the planned treatment area. In this case, given the size of the planned treatment area, two treatment applications will be necessary to treat the entire area. The center of each treatment

area is marked with an X. **C,** A pinch test is performed on the area prior to the treatment to insure that the area can be effectively elevated in the device. **D,** A baseline photograph of the treatment area is taken prior to the patient's cryolipolysis treatment. **E,** The patient is shown 16 weeks after a single cryolipolysis treatment to the abdomen. Note the significant improvement in the appearance of the thickness of the fat pad. Photos (***A*** to ***C***) courtesy of Zeltiq Inc., Pleasanton, CA. Photos (***D***) and (***E***) courtesy of Dr Flor Mayoral, Coral Gables, FL and Zeltiq Inc., Pleasanton, CA, USA.

It is important to remind the patient that the full effect of the treatment will not be visible for 2 to 3 months. In the post-procedure photo, taken 16 weeks after the patient's single cryolipolysis treatment session, a noticeable reduction in the volume and appearance of the abdominal fat "muffin top" is clearly observable (see Fig. 8.8D and E).

In a clinical study a significant reduction in the thickness of the fat in the treatment area was observed following a single CoolSculpting treatment (mean fat pad thickness reduction of 22.4%, as measured on high-resolution ultrasound). Of the 32 patients in the study, all had achieved a significant visible contour improvement following a single treatment. The best results were in patients with localized, discrete fat bulges. Another study demonstrated that 79% of patients reported clinical improvement in the appearance of their abdominal fat 2 to 4 months following a single CoolSculpting treatment. A study of 42 patients treated on the inner thighs showed a 0.9-cm circumferential reduction and 2.8-mm reduction in fat thickness, as measured by ultrasound. In these studies the treatment was well tolerated.

Patients may bruise following the procedure, likely due to the vacuum effect of the device. Many patients develop transient altered sensation, numbness, or even sharp pain in the treatment area, lasting up to 2 weeks. In rare instances the pain is sufficient to warrant treatment with pain medications. No significant changes in lipid profiles or liver function tests following cryolipolysis have been demonstrated in either the initial animal studies or human clinical studies. There is a cost for each treatment cycle for the treating physician (i.e., disposable). No cases of scarring or ulceration of the skin have been reported to date. However, there have been reports of paradoxical fat hypertrophy, where the treated area actually develops increased fat following the CoolSculpting; fortunately, this event is rare, occurring in less than 0.01% of treatments.

Pearl 7

Following a CoolSculpting treatment, gentle massage of the treated area should be performed to break up crystallized adipocytes and improve the efficacy of the treatment.

Cryolipolysis represents a novel, noninvasive treatment option for fat. Patients can undergo a safe, effective, and simple procedure, which will

gradually reduce the appearance of unwanted fat over the following 2 to 4 months. It should be noted that the device works best for localized, discrete fat bulges and is not intended for the treatment of obesity or as a substitute for large-volume liposuction.

Conclusion

The field of noninvasive body contouring has evolved rapidly in the last several years. Although liposuction and surgical procedures remain the gold standard for patients seeking large-volume fat removal, these noninvasive options represent simple procedures with limited or no downtime to improve the appearance of fat and cellulite. Topical creams, injectable agents, and physical manipulation all represent options for patients seeking noninvasive treatments.

Within the realm of lasers and light sources, there are numerous options for patients, including RF, focused ultrasound, lasers, and cryolipolysis. These technologies are relatively new, and the ultimate treatment efficacy will continue to be established through controlled clinical trials. Head-to-head studies comparing the devices are currently limited, and as a result it is difficult to definitively compare the efficacy of the devices. The best option for your patient ultimately depends on their treatment goals and expectations.

Check online videos (Video 8.1 and 8.2).

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9

Nonsurgical skin tightening

Michael S. Kaminer, Melissa A. Bogle, Macrene Alexiades-Armenakas

Summary and Key Features

- Nonsurgical skin tightening is a popular concept, with novel devices continually entering the market.
- The main types of nonsurgical skin tightening devices include radiofrequency, infrared light, and ultrasound technologies; most recently, needle-based delivery has been used.
- Treatment protocols have evolved over the years to focus on reduced energy settings or mobile techniques, making the procedures safer and more comfortable for patients.
- All skin-tightening devices work by delivering heat in the form of energy to the skin or underlying structures. They create mechanical and biochemical effects that lead to both immediate contraction of collagen fibers and delayed remodeling and neocollagenesis via wound healing.
- Patient selection is key for best results and overall patient satisfaction.
- Patients who are concerned about risk and recovery and who are willing to accept reduced efficacy in exchange for an improved side effect and healing time profile are ideal candidates for nonablative approaches.
- Noninvasive and minimally invasive skin-tightening devices are capable of improving both skin laxity and facial contours. The physician must analyze the patient's three-dimensional facial structure to determine those areas that would benefit most from the procedure. This would typically include the

upper face/brow region and the lower face/jawline region.

- Skin-tightening procedures can be performed along with fillers, neurotoxins, or other laser- or light-based devices to address multiple issues and achieve a more global overall improvement.

- Rarely, patients may experience side effects related to overly aggressive treatment, such as burns, indentations, scars, or changes in pigmentation. The overall incidence of such problems is extremely low with all current devices, owing to updated protocol trends using lower energies and patient feedback as a guide to safe energy delivery.

Introduction

The appearance of rhytides and skin laxity are near certainties during the aging process. A number of modalities have been used to reduce the appearance of rhytides and skin laxity, including laser, mechanical, and surgical techniques. In the mid- to late 1990's, ablative resurfacing lasers were deemed the gold standard for facial skin tightening. Despite substantial clinical benefits, the technology was beset with significant downtime and an increased risk of side effects, such as erythema, permanent pigmentary changes, infection, and scarring. Patients are now more accustomed to procedures with both reduced downtime and sufficient clinical improvement. This has led to a burgeoning number of nonablative technologies with little to no recovery time and a more favorable risk–reward profile. Unlike ablative lasers, nonablative technologies induce thermal injury to the dermis or subcutaneous tissues without epidermal vaporization. Epidermal protection is customarily achieved through the use of adjunctive surface cooling.

In terms of skin laxity specifically, the gold standard of treatment remains rhytidectomy or surgical redraping. The goal of this chapter is to review the major types of minimally invasive, nonablative tissue-tightening techniques, including radiofrequency-, light-, and ultrasound-based devices (Table 9.1). These devices are not a replacement for surgical procedures, and appropriate patient selection remains key to overall satisfaction.

Table 9.1

Major types of skin-tightening technologies

Skin-tightening technology	Device
Monopolar radiofrequency	Thermage (Solta)
	Pelleve (Cynosure)
Bipolar radiofrequency with light energy	Elos Plus, Galaxy, Aurora, Polaris, ReFirme (Syneron-Candela)
Bipolar radiofrequency with vacuum	Aluma (Lumenis)
Bipolar radiofrequency delivered via a microneedle electrode array	Profound (Syneron-Candela)
	Infini (Lutronic)
	Intensif (Endymed)
Broadband infrared light	Titan (Cutera)

	Icon (Cynosure)
	SkinTyte (Sciton)
Unipolar and bipolar radiofrequency	Accent (Alma)
Ultrasound technology	Ulthera (Merz)
Ultrasound with radiofrequency	Exilis (BTL Aesthetics)

Thermal collagen remodeling

All skin-tightening devices work by delivering heat in the form of energy to the skin or underlying structures. This creates mechanical and biochemical effects that lead to both immediate contraction of collagen fibers and delayed remodeling and neocollagenesis via a wound-healing response (Box 9.1).

Box 9.1

Mechanism of skin-tightening devices

1. Immediate collagen contraction by direct heating of collagen fibers

2. Delayed remodeling and neocollagenesis via a wound-healing response

Collagen fibers are composed of a triple helix of protein chains linked with interchain bonds into a crystalline structure. When collagen fibers are heated to specific temperatures, they contract due to breakage of intramolecular hydrogen bonds. Contraction causes the crystalline triple helix structure to fold, creating thicker and shorter collagen fibers. This is thought to be the mechanism of action of immediate tissue tightening seen after skin-tightening procedures. Studies have also found selective contraction of fibrous septae in the subcutaneous fat, which is thought to be responsible for the inward (Z dimension) tightening (Fig. 9.1).

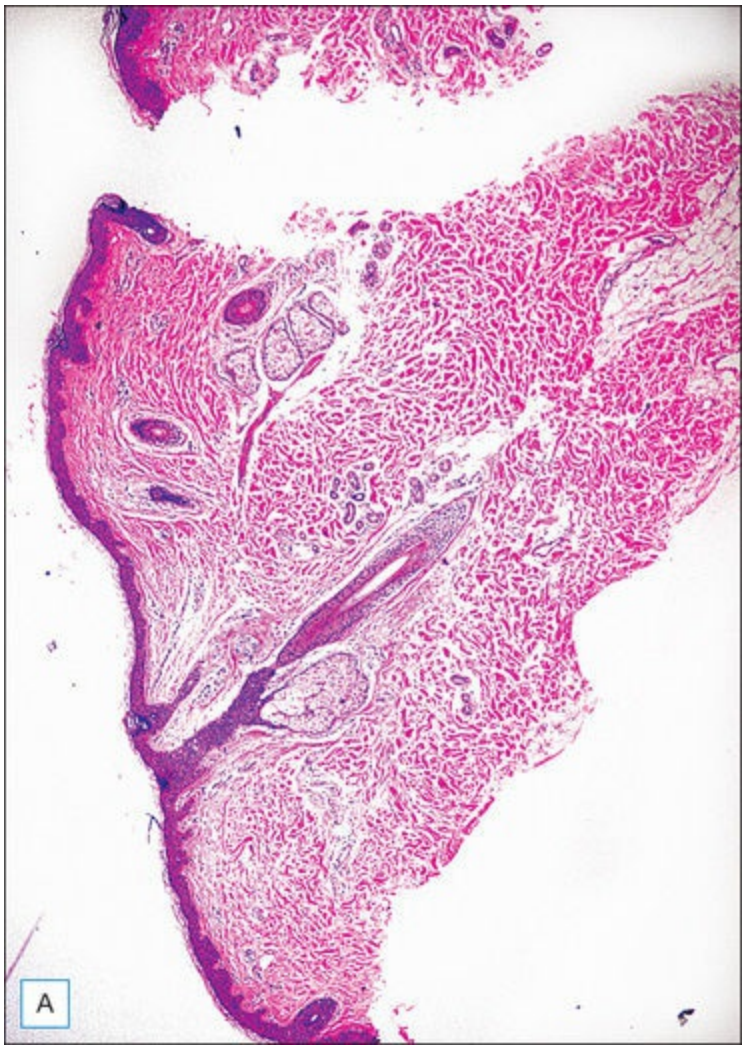

A



FIGURE 9.1 Human skin (**A**) before and (**B**) 4 months after treatment with the Thermage, showing epidermal thickening and increased dermal density. Photographs courtesy of Solta.

Problems can arise if too much heat is delivered because the collagen fibrils will denature completely above a critical heat threshold. This can lead to cell death, denaturation, and scar formation. If too little heat is delivered, there will be no tissue response, although it appears that mild thermal injury gives rise to new dermal ground substance and tissue remodeling of photodamaged skin over time. The optimal shrinkage temperature of collagen has been cited as 57°C to 61°C; however, contraction is in actuality determined by a combination of temperature and exposure time. For every 5°C decrease in temperature, a tenfold increase in exposure time is needed to achieve an equivalent amount of collagen contraction. Studies show that for exposure times in the millisecond domain the shrinkage temperature is greater than 85°C, whereas for exposure times over several seconds the shrinkage temperature is at a lower range of 60°C to 65°C.

The other main mechanism in skin rejuvenation is a secondary wound-healing response that produces dermal remodeling over time. The wound-healing response entails activation of fibroblasts to increase deposition of type I

collagen and encouraging collagen reorganization into parallel arrays of compact fibrils.

Radiofrequency devices

Radiofrequency devices have been used for hemostasis, electrocoagulation, and endovenous closure in medical dermatology. In the aesthetic arena the technology has been used for skin resurfacing and noninvasive tissue tightening.

Radiofrequency energy is energy in the electromagnetic spectrum ranging from 300 MHz to 3 kHz. Unlike most lasers, which target specific absorption bands of chromophores, heat is generated from the natural resistance of tissue to the movement of electrons within the radiofrequency field, as governed by Ohm's law (Box 9.2). This resistance, called impedance, generates heat relative to the amount of current and time by converting electrical current to thermal energy. Consequently, energy is dispersed to three-dimensional volumes of tissue at controlled depths.

Box 9.2

Ohm's law

Impedance (Z) to the movement of electrons creates heat relative to the amount of current (I) and time (t):

$$\text{Energy (Joules)} = I^2 \times Z \times t$$

The configuration of electrodes in a radiofrequency device can be monopolar or bipolar, and both have been used for cutaneous applications. The main difference between the two is the configuration of electrodes and type of electromagnetic field that is generated. In a monopolar system the electrical current passes through a single electrode in the handpiece to a grounding pad (Box 9.3). This type of electrode configuration is common in surgical radiofrequency devices because there is a high density of power close to the electrode's surface with the potential for deep penetration of tissue heating. In tissue-tightening applications, surface cooling is used to protect the outer layers of the skin and heat only deeper targets. In a bipolar system the electrical current passes between two electrodes at a fixed distance (Box 9.4). This type of electrode configuration has a more controlled current distribution; however, the depth of penetration is limited to approximately one-half the distance between the electrodes.

Box 9.3

Monopolar electrode devices

- The electrical current passes through a single electrode in the handpiece to a grounding pad
- There is a high density of power close to the electrode's surface with the potential for deep penetration of tissue heating

Box 9.4

Bipolar electrode devices

- The electrical current passes between two electrodes at a fixed distance
- The depth of penetration of the current is limited to approximately one-half the distance between the electrodes

With radiofrequency technologies, the depth of energy penetration depends upon not only the configuration of the electrodes (i.e., either monopolar or bipolar) and mode of delivery (i.e., skin surface, needle-based, or probe-based) but also the type of tissue serving as the conduction medium (i.e., fat, blood, skin), temperature, and the frequency of the electrical current applied (Box 9.5). Tissue is made up of multiple layers, including dermis, fat, muscle, and fibrous tissue, all of which have different resistances to the movement of radiofrequency energy (Table 9.2). Structures with higher impedance are more susceptible to heating. In general, fat, bone, and dry skin tend to have low conductivities such that current tends to flow around these structures rather than through them. Wet skin has a higher electrical conductivity, allowing greater penetration of current. This is why, in certain radiofrequency procedures, improved results can be seen with generous amounts of coupling fluid and increased hydration of skin. The structure of each individual's tissue (dermal thickness, fat thickness, fibrous septae, number and size of adnexal structures) all play a role in determining impedance, heat perception, and total deposited energy despite otherwise equal parameters.

Box 9.5

Factors influencing the depth of penetration of radiofrequency technologies

- Frequency of the electrical current
- Electrode configuration (i.e., monopolar or bipolar)
- Type of tissue serving as the conduction medium
- Temperature

Table 9.2

Dielectric properties for human tissue at 1 MHz and room temperature

Type of tissue	Electrical conductivity (siemens/m)
Bone	0.02
Fat	0.03
Dry skin	0.03
Nerve	0.13
Cartilage	0.23
Wet skin	0.22
Muscle	0.50
Thyroid	0.60

Temperature also influences tissue conductivity and the distribution of electrical current. In general, every 1°C increase in temperature lowers the skin impedance by 2%. Surface cooling will increase resistance to the electrical field near the epidermis, driving the radiofrequency current into the tissue and increasing the penetration depth. Conversely, target structures that have been prewarmed with optical energy will, in theory, have greater conductivity, less resistance, and greater selective heating by the radiofrequency current. This is the theoretical advantage touted by hybrid skin-tightening devices that use a combined approach of light and radiofrequency energy together giving synergistic results.

Monopolar radiofrequency

The first monopolar tissue-tightening device on the market was the Thermage device (Solta Medical, Hayward, California; Valeant Pharmaceuticals, Bridgewater, New Jersey), introduced in 2001. It remains the most exhaustively studied and published apparatus. The Thermage device uses a capacitive coupled electrode at a single contact point and a high-frequency current at a frequency of 6 MHz. A disposable membrane tip is used to deliver the energy into the skin, with an accompanying adhesive grounding pad serving as a low-resistance path for current flow to complete the circuit. The use of capacitive rather than conductive coupling is important because it allows the energy to be dispersed across a surface to create a zone of tissue heating. With conductive coupling, the energy is concentrated at the tip of the electrode, resulting in increased heating at the contact surface and an increased risk of epidermal injury (Video 9.1).

In the early clinical experience, one of the main drawbacks to the Thermage procedure was a high degree of discomfort during the procedure, requiring heavy sedation or frank anesthesia. The protocol at that time was to perform one to two passes at higher energies. The treatments were quite painful, results tended to be inconsistent from patient to patient, and some adverse events, such as fat necrosis and atrophic scarring, were noted. Over the years, treatment protocols have evolved to a paradigm using lower energies, multiple passes, and patient feedback on heat sensation as the end point of therapy. This has all but eliminated the risk of unacceptable side effects and has greatly reduced the

pain involved such that most procedures can be performed without any anesthesia. Furthermore, vibration (Comfort Pulse Technology [CPT]) has been added to the system to further enhance patient comfort. Monopolar radiofrequency energy is now commonly used to accomplish skin tightening of the face (Case Study 1), eyelids (Case Study 1), abdomen (Fig. 9.2), and extremities.

Case Study 1

A 47-year-old woman presents for a consultation regarding skin laxity on the lower face and jawline. She states she has noticed a gradual increase in sagging and jowls over the past several years and she is finding it difficult to camouflage. She has her 30th high school reunion in 4 months and states she wants improvement by then. She tells you she is not trying to look 18 again but just wants to look as good as she feels. On examination, the patient has mild-to-moderate jowl formation, with a loss of definition to her jawline. She also has a modest amount of submental laxity, absence of platysma bands, and minimal submental fat. Her skin tone and thickness are average. This patient would be a candidate for either radiofrequency skin tightening or a surgical face lift. She may be a better candidate for nonsurgical tightening because of her mild-to-moderate skin laxity without underlying structural deficits. She also has realistic expectations about results and has several months post procedure for the skin tightening to take effect before her goal event. Most of the skin-tightening technologies can be used over multiple areas of the body; however, there are a few locations that favor some devices over others. The Thermage device is an excellent choice for skin tightening of the lower face because it has a small 0.25 cm^2 tip, high eye safety profile, and lack of significant discomfort during treatment.

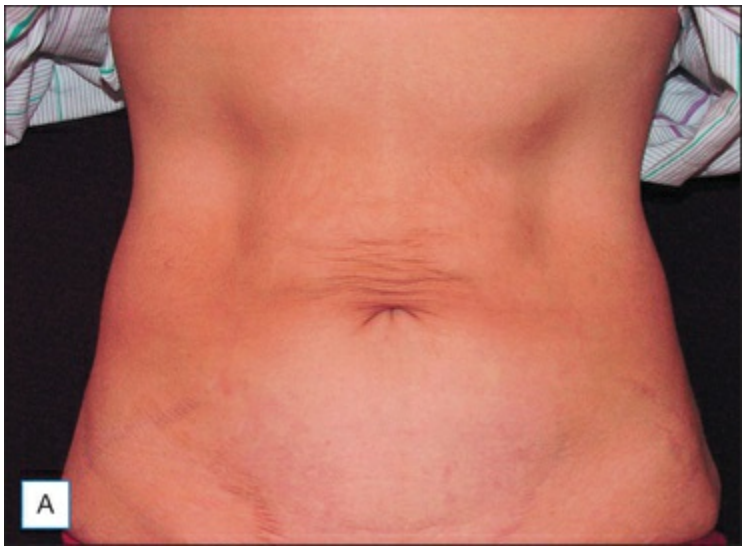




FIGURE 9.2 Tightening of abdominal skin with the Thermage: (**A**) before and (**B**) 1 year after one pass at 15.5 J.

Practitioners should focus on delivering multiple passes at modest fluence titrated to patient comfort. Focus on the jawline and submental regions with additional passes can enhance post-treatment results and patient satisfaction.

Pearl 1

Skin-tightening procedure areas should be carefully inspected post treatment for such signs as persistent erythema, localized swelling, or hives. If any of these indications are found, it may be helpful to apply a mid- to high-potency topical corticosteroid cream to reduce the incidence of crusting or pigment alteration.

The clinical results of nonablative radiofrequency skin tightening were first reported by Fitzpatrick et al. for the periorbital area in 2003. At least some degree of clinical improvement was reported in 80% of subjects (Figs. 9.3 to 9.5) In 2006 Dover et al. compared the original single-pass, high-energy technique with the updated low-energy, multiple-pass technique, using immediate tissue tightening as a real-time end point. With the original treatment algorithm, 26% of patients saw immediate tightening, 54% observed skin tightening at 6 months, and 45% found the procedure overly painful. With the updated protocol, 87% had immediate tissue tightening, 92% had some degree of tightening at 6 months, only 5% found the procedure overly painful, and 94% stated the procedure matched their expectations (Fig. 9.6). The low-energy, multiple-pass protocol has also been reported to be significantly safer, lowering the incidence of adverse events to less than 0.05%.

Pearl 2

Because skin-tightening procedures can cause significant discomfort, patient pain feedback should be used as the basis for choosing particular energies in a

given treatment area for each individual. With updated treatment protocols, anesthesia is usually not required. The use of nerve blocks and intravenous sedation should not be used as some degree of pain feedback from the patient is necessary to limit side effects and enhance patient safety. Local infiltration anesthesia is also not recommended because it may alter the inherent tissue impedance and can increase adverse effects. If in doubt, it is safest to use the lowest possible treatment settings.

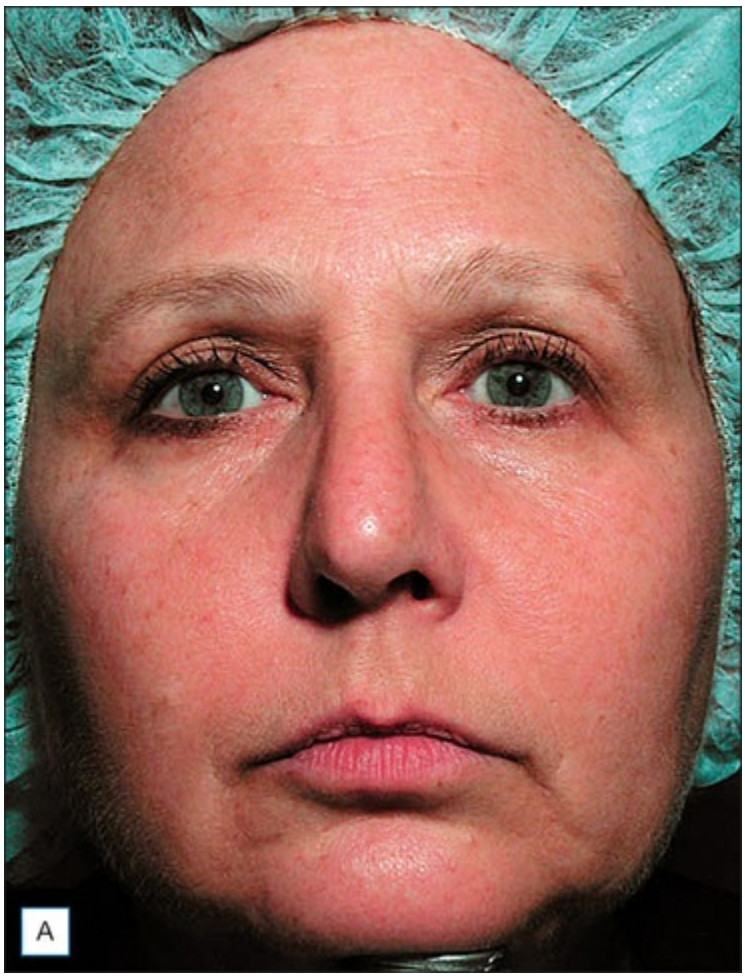




FIGURE 9.3 Eyebrow lift following Thermage treatment: (**A**) baseline and (**B**) 4 weeks post treatment with a mean lift of 3.42 mm *(right brow)* and 3.41 mm *(left brow)*. Photographs courtesy of Solta.



FIGURE 9.4 Periorbital rejuvenation following Thermage treatment: (**A**) baseline, (**B**) 2 months post treatment, and (**C**) 4 months post treatment. Photographs courtesy of Solta.

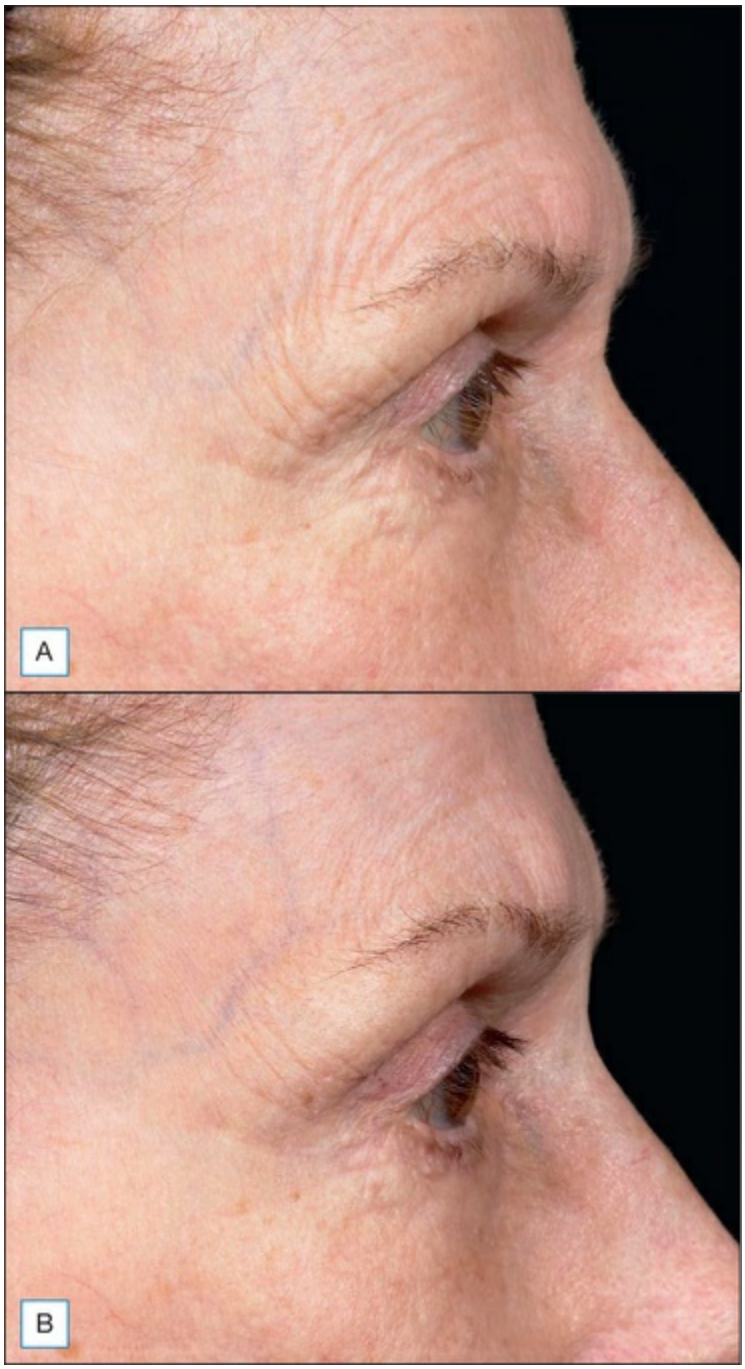


FIGURE 9.5 Periorbital rejuvenation following Thermage treatment: (**A**) baseline and (**B**) 4 months post treatment. Photographs courtesy of Solta Medical Aesthetic Center.



FIGURE 9.6 Lower face skin tightening following Thermage treatment: (**A**) baseline and (**B**) 3 months post treatment. Photographs courtesy of Dr Ivan Rosales.

Bipolar radiofrequency

The prototype device using needle-delivered bipolar radiofrequency is the Profound (Candela-Syneron, Wayland, Massachusetts). The Profound device differed from other applications on the market in that it pioneered a microneedle electrode array to deliver bipolar radiofrequency energy into the reticular dermis while bypassing the epidermis and papillary dermis. Single-use treatment cartridges are used that contain five independently controlled, 32-gauge, bipolar microneedle pairs. The 250-μm needles are spaced 1.25 mm

apart, and each needle pair is independently powered by the generator. The needles are 6 mm long, with the top 3 mm insulated to protect the superficial portion of the skin during treatment, and the bottom 3 mm exposed to allow electrical current flow. The needles are inserted at a 25-degree angle to the epidermis so that the tip of the needle is 2 mm from the epidermis. Insertion is done by spring-loaded injection. Because current flows between the two needles in each pair, the radiofrequency energy creates fractionated zones (one between each pair) of thermal injury situated in the deep dermis 1 to 2 mm from the surface of the skin. Epidermal cooling is achieved via an integrated thermokinetic cooling bar on the applicator. This approach creates zones of thermal injury with real-time temperature monitoring with temperature sensors in each electrode tip to help to maintain a preselected target temperature regardless of varying skin conditions and improves consistency between patients.

Alexiades-Armenakas et al. compared baseline and 3- to 6-month follow-up photographs of 15 patients who underwent skin tightening using a microneedle radiofrequency device with those of six patients who had undergone rhytidectomy. The radiofrequency device patients were judged to have a 16% improvement from baseline, and the surgical patients were judged to have a 49% improvement from baseline. The authors concluded from this that the mean laxity improvement from a single microneedle radiofrequency treatment was 37% that of a surgical facelift. In the multicenter clinical trial and multiarm studies of target dermal temperatures ranging from 52 to 78°C, it was discovered that the temperature 67°C cohort resulted in maximal neocollagenesis, neoelastogenesis, and hyaluronic acid production and correlated clinically with maximal rhytid and laxity reduction and a 100% response rate. Higher and lower target temperatures demonstrated less efficacy. The findings made possible by needle-delivered radiofrequency support the author's theory that partially denatured collagen is more effective at triggering a strong wound healing response. A clinical example of a subject at baseline and at 6 months following a single treatment with microneedle radiofrequency (Profound; Syneron Candela, Wayland, Massachusetts) is shown in Figs. 9.7 to 9.9.



FIGURE 9.7 Baseline and after Profound needle-delivered bipolar radiofrequency.



FIGURE 9.8 Baseline and after Profound needle-delivered bipolar radiofrequency.



FIGURE 9.9 Baseline and after Profound needle-delivered bipolar radiofrequency.

A number of additional needle-delivered bipolar radiofrequency devices have emerged. One such device, the Infini (Lutronic, Burlington, Massachusetts) provides the feature of adjustable needle depths to 0.5, 1.0, 1.5, 2.0, and 3.5 mm. The device offers a 49 needle tip (10 mm × 10 mm, 7 × 7 needles) and a 16 needle tip (5 mm × 5 mm, 4 × 4 needles). The microneedles are made from surgical stainless steel coated with gold for conductivity and then double coated with an insulating silicon compound, except for the first 300 μm of the tip. The needles have a diameter of 200 μm and a point diameter of 20 μm. The insulation of the needle shaft means that the active area of the microneedle electrodes is restricted to the tip, and there is no electrothermal

damage delivered to the epidermis. Clinical trials have demonstrated wrinkle reduction following treatment with this device, with clinician-assessed overall efficacy and patient satisfaction index similar at from 80.7% to 88.9% and 81.3% to 85.9%.

Another microneedle fractional bipolar radiofrequency device is the Intensif (EndyMed Medical, Caesarea, Israel). The handpiece uses 25 noninsulated gold-plated microneedle electrodes with a maximum diameter of 300 μm at their base gradually tapered to a sharp edge. Penetration depth is up to 3.5 mm with digitally controlled increments of 0.1 mm. Maximal power is 25 W with a maximal pulse duration of 200 ms. When the needles reach the predefined insertion depth, the radiofrequency is emitted selectively, heating the dermis while sparing the epidermis. The difference in electrical impedance between the epidermis (high impedance) and the dermis (low impedance) ensures radiofrequency flow through the dermis. The radiofrequency emission delivered over the whole dermal portion of the needle allows effective coagulation resulting in minimal or no bleeding, combined with deep dermal heating.

Another device is the Fractora (Invasix, Irvine, California), which uses 24 radiofrequency conducting needles, alternating current with two long side electrodes. Each needle is 2500 μm long and 200 × 300 μm wide at the base. The coated needles are insulated along 2000 μm, leaving the distal 500 μm uncoated. The handpiece is loaded to the Fractora platform (also applicable to InMode or BodyTite platforms; Invasix Ltd./InMode MD Ltd., Israel). The device has been reported to result in significant improvement in acne and acne scars.

A subdermal, probe-delivered, monopolar radiofrequency device has been developed using Thermi (ThermiAesthetics, Irving, Texas), to deliver radiofrequency energy to the subdermal plane. A blunt, 10-cm-long, 18-gauge percutaneous treatment probe is inserted, and the distal end administers the radiofrequency. A temperature sensor is located in the probe tip that initiates an automatic feedback loop to maintain subdermal tissue temperature. The device is set to maintain a 50°C to 60°C temperature in the subdermal plane. Subdermal temperatures of 65°C and 50°C correlate with skin surface temperatures of 41.6°C and 41.1°C, respectively.

Combined electrical and optical energy

Another type of skin-tightening device combines radiofrequency energy with optical energy from laser or light sources. The currently available combined electrical and optical energy devices use bipolar electrodes and include the Galaxy, Aurora, Polaris, and ReFirme systems (Syneron Candela). The hypothetical advantage to these devices is that the two forms of energy may act synergistically to generate heat. Target structures that have been prewarmed with optical energy will, in theory, have greater conductivity, less resistance, and greater selective heating by the radiofrequency current. No grounding pad is required as the current flows between the electrodes rather than throughout

the remainder of the body as with monopolar systems. One major adverse event noted with these devices is known as tissue arcing, which can result in tissue burns and possible scar formation. Proper technique will help to avoid the issue because arcing has been associated with the handpiece not being properly placed in contact with the skin.

The technology has been used in hair removal, wrinkle reduction, skin tightening, and the treatment of both pigment and vascular disorders (Case Study 2). The premise is that less radiofrequency energy is ultimately needed for proper collagen denaturation and remodeling. The major disadvantage to these devices is that bipolar radiofrequency energy does not penetrate very deep into the skin. There is also some criticism that bipolar radiofrequency is unable to produce a uniform, volumetric heating response comparable to monopolar radiofrequency. Furthermore, because the bipolar radiofrequency devices are often combined with other light-based technologies, it is difficult to assess exactly how large a role bipolar radiofrequency plays in the clinical outcomes of such treatments.

Case Study 2

A 54-year-old male presents to your office and states that he has been recently divorced and wants to improve his appearance so that he feels more comfortable reentering the dating scene. He states he is against injectable treatments, such as botulinum toxin or fillers, because he does not want to put what he calls "foreign substances" in his body and he does not want to have to come into the office for repeated maintenance. On examination, he has fair skin with scattered lentigines on the cheeks and forehead and fine telangiectasias over the cheeks and nose, creating a blush-type erythema. He has early changes consistent with skin laxity predominantly in the midface region, brow, and jawline.

For this patient, combined electrical and optical energy may be the best option to treat skin laxity in combination with other signs of photodamage such as lentigines or telangiectasias. A 2002 study by Bitter evaluating a series of three to five combined intense pulsed light and radiofrequency energy treatments on photoaged skin revealed a 70% improvement in erythema and telangiectasia, a 78% improvement in lentigines, and a 60% improvement in skin texture, as determined by subject satisfaction levels. Because these devices can also be used for hair removal, caution should be used in treating the lower face and neck in a male patient so as to not thin or remove the beard. Prudence should also be used when treating darker skin types or tanned skin with devices using an optical component absorbed by pigment. As a general guideline, optical fluences should be lowered by a minimum of 20% when treating darkly pigmented lesions or dense pigment irregularity, even in light-skinned patients, to avoid side effects such as burns, crusting, or pigmentary alteration.

Pearl 3

Most skin-tightening treatments using radiofrequency, ultrasound, and infrared light are generally safe in all skin types. The exception is technologies that use an optical component absorbed by pigment, such as the intense pulsed light–radiofrequency combination. In these cases, caution should be exercised when treating Fitzpatrick skin types IV to VI, lighter-skin type patients with a tan, darkly pigmented lesions, or areas of dense pigment irregularity.

In 2005 Doshi and Alster conducted one of the first studies using combined diode and radiofrequency technology with a series of three treatments in 20 female subjects (radiofrequency: 50 to 85 J/cm^2, optical energy: 32 to 40 J/cm^2). Energy was increased with each session, based on the patient's pain tolerance and a clinical response of immediate erythema and edema. Modest improvement was seen in all patients at 3 months; however, improvement was found to be slightly reduced at 6 months. In 2005 Sadick et al. conducted a two-center study using combination intense pulsed light and radiofrequency (radiofrequency: up to 20 J/cm^2, optical energy: 30 to 45 J/cm^2) over five treatments for facial rhytides and skin laxity. Modest improvements were reported. Side effects were minimal, but some instances of crusting occurred. In 2007 Yu et al. used combination radiofrequency and infrared energy to study skin tightening in a three-treatment series on 19 female Asian patients (radiofrequency: 70 to 120 J/cm^2, optical energy: 10 J/cm^2). Objective assessment showed mild-to-moderate improvement in 26% to 47% of areas treated (see Figs. 9.8 and 9.9).

Vacuum-assisted bipolar radiofrequency

Bipolar radiofrequency has been combined with an accompanying vacuum apparatus in an attempt to take advantage of several benefits of vacuum technology. The first device to do this was the Aluma (Lumenis, Santa Clara, California), using what has been termed FACES (functional aspiration controlled electrothermal stimulation) technology. The vacuum apparatus suctions a fold of skin in alignment between two electrodes. Nontarget structures, such as muscle, fascia, and bone are avoided. The theory is that this may help to overcome the depth limitations inherent in bipolar radiofrequency technology by bringing the target tissue closer to the electrodes. Less overall energy may also be required for effective treatment. It has also been hypothesized that increased blood flow and mechanical stress on fibroblasts from the vacuum suction may lead to increased collagen formation. Vacuum technology has the added benefit of helping to reduce procedure discomfort.

In a pilot study of 46 adults undergoing eight facial treatments with vacuum-assisted bipolar radiofrequency, Gold found significant improvement in skin texture. The mean elastosis score of study participants went from 4.5 before treatment to 2.5 by 6 months post treatment, indicating a shift from moderate to mild elastosis. The authors noted a short-term tightening effect due to collagen

contraction followed by a gradual, long-term improvement due to the wound-healing response and neocollagenesis. Although subjects were generally pleased with the treatment outcome, their satisfaction levels declined somewhat during the follow-up period. This can be a common finding in radiofrequency skin treatments owing to delayed neocollagenesis and long-term wound-healing response. Subjects may have difficulty accurately remembering the exact condition of their skin before treatment, particularly when 6 or more months have passed.

Pearl 4

It is essential to take standardized photographs before skin-tightening procedures. Care should be taken to use identical positioning and lighting conditions in all photography sessions because subtle differences can distort appearance and alter perceived outcomes. Pretreatment and posttreatment photographs may need to be compared because changes with skin-tightening procedures may be subtle to the patient, especially after several months have passed.

Hybrid monopolar and bipolar radiofrequency

The first system to combine monopolar and bipolar radiofrequency in one device was the Accent (Alma Lasers, Buffalo Grove, Illinois). The theory behind using both types of radiofrequency is to deliver different depths of current to the skin. The bipolar electrode handpiece allows for more superficial, localized (nonvolumetric) heating based on tissue resistance to the radiofrequency conductive current. The monopolar electrode handpiece targets deeper, volumetric heating via the rotational movement of water molecules in the alternating current of the electromagnetic field. The monopolar handpiece delivers a higher amount of energy because it theoretically is heating a greater tissue volume than the bipolar handpiece. The monopolar handpiece is typically used to treat the forehead, cheeks, jawline, and neck. The bipolar handpiece is used to treat the glabella, lateral periorbital area (Fig. 9.10), upper lip, and chin (Fig. 9.11). Despite the use of monopolar radiofrequency, this particular system uses a closed system in which no grounding plate is required (Case Study 3).



FIGURE 9.10 Lower face skin tightening: (**A**) before and (**B**) immediately following a single treatment with the Galaxy device.





FIGURE 9.11 Skin tightening of the neck and jawline region: (**A**) before and (**B**) immediately following a single treatment with the Accent treatment. Photographs courtesy of Dr Alexiades-Armenakas.

Case Study 3

A 42-year-old woman comes into your office complaining of skin laxity in the upper arm area. She states that she is no longer comfortable wearing sleeveless clothing because she feels like her arms look like what she calls "cottage cheese." She states she has always maintained a relatively normal weight. On examination, she is of a normal weight for her height and build. She has mild-to-moderate skin laxity predominantly in the posterior portion of her upper arm and dimpling in the texture of both the anterior and posterior surface of the arms. In this case the patient has two main options for improvement, including upper arm liposuction and nonsurgical skin tightening. She may be a better candidate for nonsurgical skin tightening because the textural abnormality in her upper arms extends around the full circumference. Liposuction would predominantly improve the skin in the "bat wing" area on the posterior portion of the arm. She would not be a candidate for surgical brachioplasty, due to her young age, milder degree of laxity, and desire to wear sleeveless clothing. In this case the hybrid Accent device might be a good choice for tissue tightening, with the added benefit of possible volume reduction.

One case report compared treating skin laxity on one arm with the Thermage device and the opposite arm with the Accent device. The Thermage arm was treated with a single treatment at settings of 351.5 to 354, with a minimum of six passes on the inner arm and three passes on the outer arm (1200 pulses total). The Accent arm was treated with a series of nine treatments at 2-week intervals using the monopolar handpiece at an epidermal temperature of 42.5°C with three therapeutic phase passes. Although skin texture improved with both treatments, the Accent-treated arm was reported to be tighter and firmer after just two treatments, with a looser-fitting clothing sleeve. Because the Thermage-treated arm did not have a looser fitting clothing sleeve until the physician had

gone back at the end of the study and performed two Accent treatments, the author suggested that the Accent radiofrequency energy penetrates deeper and may be the device of choice when patients require both tissue tightening and volume reduction.

In 2007 Friedman treated 16 patients with a hybrid monopolar and bipolar radiofrequency device; 56% of participants had at least some degree of improvement in the appearance of rhytides and skin laxity. Twelve patients had cheek treatments, with five achieving 51% to 75% improvement and two achieving greater than 75% improvement. Nine had jowl treatments, with four achieving 51% to 75% improvement and one achieving greater than 75% improvement. Younger patients (25 to 45 years of age) were found to have a higher satisfaction rate than older patients.

Pearl 5

Studies suggest that younger patients may respond better than older patients. This may be because heat-labile collagen bonds are progressively replaced by irreducible multivalent crosslinks as the tissue ages, such that the skin of older individuals is less amenable to heat-induced tissue tightening. Skin quality is more important than the absolute age of the patient. Older patients with relatively good skin quality can respond just as well as their younger counterparts.

The Pelleve device (Cynosure Inc., Westford, Massachusetts) has taken advantage of a dual monopolar and bipolar radiofrequency-based surgical unit normally used for tissue cutting and coagulation to make it suitable for skin-tightening procedures. The system works with the use of reusable probes that are plugged into the system and applied over the skin in a circular or linear pattern to heat the subdermal tissue. A coupling gel is used to ensure proper coupling between the electrode and the patient and to help protect the epidermis. As with other skin-tightening devices, the gentle heating induces collagen denaturation, contraction, and subsequent synthesis. Repeat treatments have been shown to improve the appearance of wrinkles and skin laxity, but results are somewhat limited due to the discrete amount of energy applied. Early protocols recommended 8-weekly treatments for best results, but the treatment paradigm has since been revised to two to four treatments spaced 1 month apart, with some patients requiring an additional treatment.

Infrared light devices

Broadband infrared light in the range of 800 to 1800 nm, depending on the device, has been used for nonablative tissue tightening. The infrared rays are selectively filtered to achieve gradual heating of the dermis, with pre, parallel, and post cooling to ensure epidermal protection. The first such light-based system on the market was the Titan (Cutera, Brisbane, California). It uses light energy in the range of 1100 to 1800 nm to target water as a chromophore,

causing collagen denaturation and ultimately collagen remodeling and tissue tightening. The Icon (Cynosure) delivers energy through the handpiece of the device at a wavelength range of 850 to 1350 nm, which also targets water as the principal chromophore. Multiple treatments are required for optimal results. The SkinTyte device (Sciton, Palo Alto, California) uses light at a wavelength range of 800 to 1400 nm.

In 2006 Ruiz-Esparza performed one to three treatments on 25 patients using broadband infrared light from 1100 to 1800 nm. Most patients showed improvement ranging from minimal to excellent, with immediate skin tightening visible in 22 of the 25 patients. Three patients showed no improvement. The best results were achieved when using a combination of lower fluences and a high number of pulses. Patients treated at 30 J/cm^2 expressed no pain during the procedure and had a high degree of satisfaction immediately post procedure. The same year, Zelickson et al. looked at ultrastructural changes in cadaver and human skin post treatment. Collagen fibril alteration was found to be highest with greater fluences and depths of 1 to 2 mm. Marginal results were observed at shallower depths and lower fluences, which were possibly due to the effect of contact cooling. Comparison of the two studies emphasizes that clinical skin tightening does not always correlate with immediate positive histologic findings. This is explained by the fact that full clinical effect may take weeks to months to be demonstrated, owing to a secondary wound healing response.

In 2006 a multicenter study reported longer-term, 12- to 18-month, results using the 1100- to 1800-nm infrared device at 34 to 36 J/cm^2. Results were both immediate and delayed up to 6 months. Clinical outcomes ranged from mild to moderate in most patients. The authors concluded that using a lower fluence range of 30 to 40 J/cm^2, two to three treatments, one to two passes, and extra passes on areas that need immediate contraction or along vector lines yielded best results.

In 2009 Alexiades-Armenakas demonstrated that mobile delivery of broadband infrared light (1100 to 1800 nm, Titan; Cutera) allowed for delivery of 30% higher fluences of 44 to 46 J/cm^2. Improvement in skin laxity was demonstrated following two monthly treatments consisting of 300 to 450 pulses per treatment. Skin surface temperatures of 41°C to 42°C are attained rapidly and maintained throughout the treatment with the mobile technique.

Pearl 6

When treating the face, the physician should look at the face as distinct regions. Although the entire face can be treated in one session, it is also possible to treat segmental areas alone, such as the forehead, the eyelids, or the cheek/jawline region. However, treatment of broader surface areas and treatment of areas adjacent to the described area of laxity may improve results.

Complications were limited to minor erythema, but a few blisters were observed in areas that were overtreated. In 2007 Goldberg et al. noted positive

results in 11 of 12 patients receiving two treatments with the same device (30 to 36 J/cm^2). The best results were observed in patients who had loose draping skin, with less significant results in sagging skin that was firmly associated with the subcutaneous tissue. No improvement was noted in the jowl region.

Pearl 7

Nonsurgical skin tightening is best suited to patients with mild-to-moderate skin laxity without significant underlying structural ptosis. Patients with underlying structural laxity, including that of the facial musculature or superficial muscular aponeurotic system (SMAS), and patients with an excessive amount of skin laxity are likely to have limited to no improvement and should be counseled on other methods of rejuvenation including surgery.

Other laser wavelengths that have been used for tissue tightening include the 1064- and 1320-nm wavelengths. The chromophores for the 1064-nm wavelength, in decreasing order, are melanin, hemoglobin, and water, and the primary chromophore for the 1320-nm wavelength is water. A 2005 study by Taylor and Prokopenko compared a single treatment using a monopolar radio frequency system (73.5 J/cm^2) with a single treatment using the 1064-nm neodymium:yttrium-aluminum-garnet (Nd:YAG) laser at 50 J/cm^2. The 1064-nm laser side was deemed to have better overall results in terms of improvement in wrinkles and skin laxity, although only modest improvements were noted with both modalities. Another study in 2007 by Key compared a single facial treatment with a monopolar radiofrequency system (40 J/cm^2) to the 1064-nm Nd:YAG laser (73 to 79 J/cm^2). The 1064-nm laser resulted in greater improvement on the lower face, whereas improvement on the upper face was equivalent with both modalities. In 2001 Trelles et al. treated 10 patients with a series of eight treatments using a 1320-nm laser system (30 to 35 J/cm^2). Clinical improvement was subtle, with only two patients reporting satisfaction with the procedure. The authors suggested that combining laser treatment with parallel epidermal treatment may yield better results and achieve higher patient satisfaction.

Pearl 8

Combination therapy is a leading theme in cosmetic dermatology. Patients are able to achieve a better overall result when procedures, such as nonsurgical skin tightening, are combined with other therapies, such as botulinum toxin, fillers, and other modalities. For example, patients desiring a brow lift and a more defined jawline may achieve benefit from the use of botulinum toxin to the superolateral orbicularis oculi and platysma muscles in addition to skin tightening. Fillers can be used to achieve additional lift in the midface, brow/temples, prejowl region, and jawline.

Ultrasound devices

High-intensity focused ultrasound (HIFU) has become a foundation in the skin-tightening technology realm. When an intense ultrasound field vibrates tissue, friction is created between molecules, causing them to absorb mechanical energy and leading to secondary generation of heat. Thus the primary mechanism responsible for tissue necrosis with HIFU treatment is heating of the tissue due to the absorption of acoustic energy. This ideally leads to immediate tissue contraction and delayed collagen remodeling with the coagulative change limited to the focal region of the ultrasound field. In reality, the spectrum of cellular changes depends on the rise in temperature and the exposure duration and can range from total necrosis to subtler ultrastructural cell damage with modulation of cellular cytokine expression.

HIFU for skin-tightening applications uses short, millisecond pulses with a frequency in the megahertz domain, rather than kilohertz, as is used in traditional HIFU, to avoid cavitational processes. HIFU for skin applications also uses significantly lower energies than traditional HIFU, 0.5 to 10 J versus 100 J, which allows thermal tissue changes without gross necrosis. The main advantage to HIFU is the potential for greater depth of skin changes than other technologies with the added benefit of precisely controlled, focal tissue injury. Ultrasound energy is able to target deeper structures in a select, focused fashion without secondary scatter and absorption in the dermis and epidermis. Early research on human cadaveric tissue showed HIFU energy was able to target the facial superficial muscular aponeurotic system (SMAS) to produce discrete zones of thermal injury while sparing nontargeted adjacent structures.

The first HIFU device on the market is the Ulthera system (Merz Aesthetics, Raleigh, North Carolina). The system incorporates ultrasound imaging capability for visualizing the skin and deep tissue in combination with a therapeutic ultrasound module that creates small, approximately 1 mm^3, wedge-shaped zones of thermal coagulation. The thermally induced zones result from selective absorption of ultrasound energy in the area of geometric focus of the beam. The depth and volume of the thermal lesions are determined by the preset focus depth and frequency of the probe in combination with the intrinsic characteristics of the tissue being treated. The source energy is an adjustable parameter. Higher-frequency probes are associated with a more superficial tissue effect, whereas lower-frequency probes are associated with a deeper tissue effect. Typically, higher-frequency probes are typically used to treat areas of thinner skin, such as that of the neck, whereas the lower-frequency probes are used to treat areas of thicker skin such as the cheeks.

Current protocols aim for a geometric focal depth of therapy in the superficial to deep dermis. One of the first clinical trials by Alam et al. in 2010 assessed the safety and efficacy of HIFU on skin tightening. Significant improvement was seen in brow elevation in more than 83% of treated patients with an average increase in brow elevation of 1.7 to 1.9 mm (Fig. 9.12). Results developed over a 90-day period following treatment and were still noticeable at 10-month follow-up. The authors found lower face tightening more difficult to assess due to a

lack of fixed anatomic landmarks. In 2011 Suh et al. treated 22 Asian patients with facial skin laxity with HIFU; 77% of patients reported much improvement in the nasolabial folds, and 73% reported much improvement in the jaw line. Histologic evaluation of skin samples showed greater dermal collagen with thickening of the dermis and straightening of elastic fibers in the reticular dermis after treatment (Figs. 9.13 to 9.16).

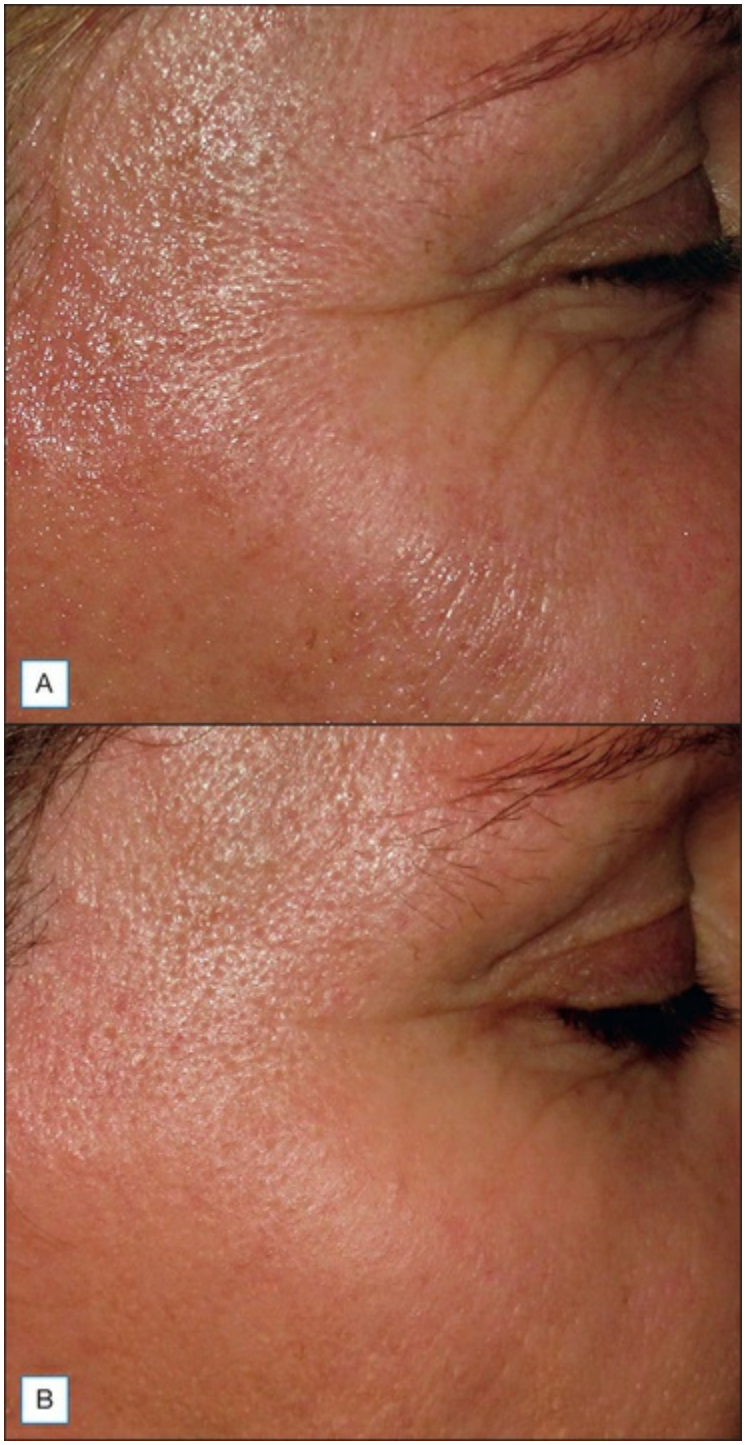


FIGURE 9.12 Periorbital rejuvenation: (**A**) before and (**B**) 3 months after four treatments with the Accent treatment. Photographs courtesy of Dr

Alexiades-Armenakas.



FIGURE 9.13 Cellulite treatment on the right leg following five treatments with the Accent and the left leg serving as an untreated control. Photograph courtesy of Dr Alexiades-Armenakas.





FIGURE 9.14 Periorbital rejuvenation and brow lift following Ultherapy treatment: (**A**) baseline and (**B**) post single-depth treatment using the 3.0-mm transducer or 4.5-mm transducer depth based on the periorbital region. Photographs courtesy of Dr Jeffrey Dover.





FIGURE 9.15 Lower face skin tightening following Ultherapy treatment: (**A**) baseline and (**B**) post dual-depth treatment at 3.0- and 4.5-mm depths. Photographs courtesy of Ulthera Inc.

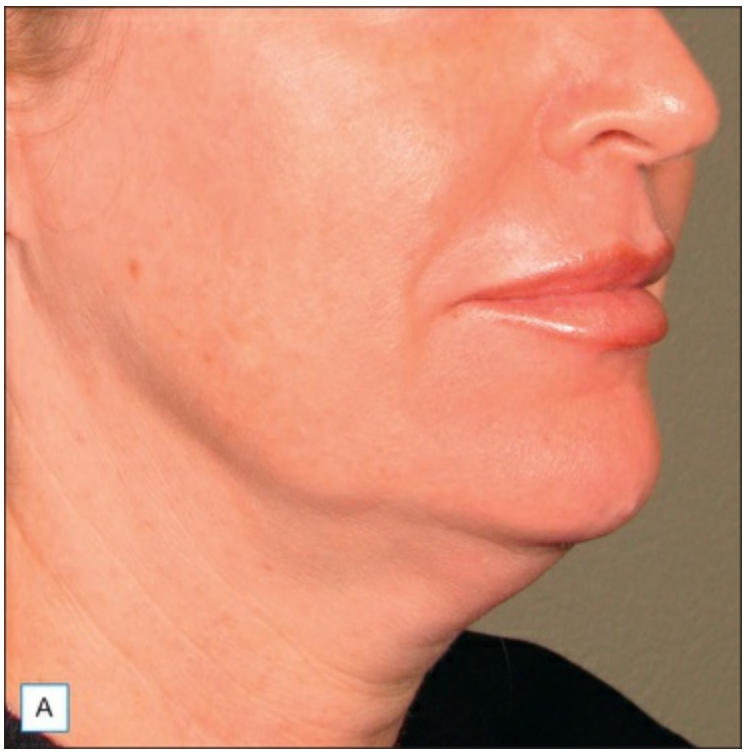




FIGURE 9.16 Lower face skin tightening following Ultherapy treatment: (**A**) baseline and (**B**) post dual-depth treatment at 3.0- and 4.5-mm depths. Photographs courtesy of Ulthera Inc.

Tips for maximizing patient satisfaction

Patient selection is of utmost importance in ultimate satisfaction with nonsurgical skin-tightening technologies. Patients must be counseled that maximum results are slow and occur over a period of 3 to 6 months. In terms of expectations, these technologies should not be thought of as an equivalent technology to surgical lifting but as an alternative option for a certain subset of patients. Despite a number of clinical studies reporting significant improvement in the appearance of lax skin, most patients show only mild-to-moderate improvement. It appears that patients who are younger with a lesser degree of skin laxity may yield the most promising clinical outcomes; skin laxity without a significant muscular attachment also appears to yield better results (Case Study 4). Very old adults with severe sagging and wrinkles are generally suboptimal candidates for the degree of improvement expected with noninvasive tightening devices (Case Study 5). Interestingly, many patients report that when skin-tightening procedures are performed at 1 to 2 year intervals, the progression of sagging and laxity appears to slow when compared with before treatment.

Case Study 4

A 78-year-old woman presents for a consult regarding general photoaging. She has avoided sun exposure her whole life and is a devoted wearer of sunscreen.

She tells you she has been going to an esthetician for the past 15 years who gives her light glycolic peels every few months. She has also used a prescription tretinoin cream given to her by her general dermatologist for the past 25 years. She is otherwise healthy and would like to improve her appearance, but she would like to get your advice on what she needs. She has never had surgery before and tells you that she would like to avoid having a facelift, if possible. On examination she has remarkably preserved skin quality with very few deep lines and no major pigmentary issues, owing to her diligent sun protection and long-term use of topical rejuvenation therapies. She does have some loss of definition along the jawline, with mild-to-moderate jowling, deepening of the nasolabial folds, descent of the eyebrow, and volume-related changes in the midface region. She also has prominent platysmal banding visible in the neck region. This patient would be an ideal candidate for almost any of the noninvasive skin-tightening approaches in combination with other therapies, such as neurotoxins and fillers, to augment her results. Although studies have shown that younger patients tend to have better results than older patients after tissue-tightening procedures, this patient has extremely good skin quality and can be expected to have at least some degree of improvement. Because the skin-tightening procedure will not address her underlying changes in facial volume and musculature, performing adjunctive therapies, such as botulinum toxin to the superolateral orbicularis oculi and platysma muscles, would help her to lift the brow, decrease banding on the neck, and achieve a more defined jawline. Filler to her midface region, nasolabial folds, prejowl region, and jawline would also be of use to restore underlying structure, increase the lifting effect, and give a more youthful shape to the face. A 2006 study by Shumaker et al. showed monopolar radiofrequency skin tightening to be safe when performed over multiple soft tissue fillers and indicated it may even have some synergistic effects in terms of long-term collagen growth. The patient has proven she is not averse to maintenance therapies and she will achieve a better overall result with global rejuvenation.

Case Study 5

A 66-year-old woman comes to your office to discuss options regarding skin laxity on her face. She states she has always loved the sun and shares tales of her days lying out on her roof with a foil blanket, covered in baby oil and iodine. She states she does not purposely tan anymore, but her husband loves to play golf and go boating. She normally accompanies him, but she has not been able to since she was diagnosed with an irregular heart rhythm last year and her cardiologist implanted a pacemaker. During the consultation, she pulls her facial skin back tautly with her hands and tells you her wrinkles do not bother her, but she would be happy if she could get rid of her sagging skin. On examination, the patient has a thin body habitus with severe solar elastosis and significant skin laxity. This is a difficult patient clinically because she is not a good candidate for nonsurgical skin tightening for several reasons. The first

issue is her pacemaker device. Radiofrequency treatments are contraindicated in patients with pacemakers, internal defibrillators, or metal implants in the face. This also makes her an undesirable candidate for a surgical facelift. Although she could undergo nonsurgical skin tightening with ultrasound or one of the broadband infrared light devices, she has very poor skin quality and a considerable degree of laxity. This, combined with her desire for facelift-like results, would most likely lead to disappointment after the procedure.

Patients should be told that nonablative skin tightening is not a substitute for a facelift and that results may be modest (Box 9.6). A small number of patients perceive no improvement at all. Patients should also be counseled that nonablative skin tightening alone is not effective for the textural aspects of photoaging, including wrinkles and pigmentary alterations. Long-term studies to examine the longevity of skin tightening have not been performed, but it appears patients can expect at least a period of a year or more before touch-up treatments are required. More research also needs to be done comparing the devices themselves to determine precise advantages of one over another.

Box 9.6

Relative predictors of success in nonablative skin-tightening procedures

- Younger patients with a lesser degree of skin laxity
- Skin laxity without a significant muscular attachment
- Realistic expectations and willingness to trade a substantial degree of tightening for little to no recovery time and minimal risk

Conclusion

The quest for nonsurgical skin tightening has led to a burgeoning number of devices on the market. Although dermal remodeling may occur with radiofrequency-, optical-, and ultrasound-based devices, patients and physicians should not expect results to be similar to those seen after surgical or possibly even ablative techniques. The techniques appear best suited for younger patients with mild-to-moderate skin laxity without a significant degree of underlying structural ptosis. Physicians must appreciate the indications, complications, benefits, and limitations of each device. The key to success remains rooted in patient selection and management of expectations. It is still uncertain as to how many treatments are ideal for the majority of these medical devices and how long the effects will be maintained. Future research and clinical trials will continue to refine techniques and delivery systems for optimal results.

Check online videos (Video 9.1 and 9.2).

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10

Laser treatment of ethnic skin

Henry H.L. Chan, Stephanie G.Y. Ho



Summary and Key Features

- The use of lasers and lights can be safe and effective in ethnic skin.
- Sun protection before and post treatment, together with the use of bleaching agents, is important in reducing the risks of postinflammatory hyperpigmentation.
- Q-switched and long-pulsed lasers are both useful in the treatment of epidermal pigmentation; however, in ethnic skin, long-pulsed lasers are preferred because they have similar efficacy with fewer side effects.
- Using a small spot size avoids inadvertent treatment of surrounding normal skin, which can increase the risk of hyperpigmentation when the contrast between lesional and nonlesional skin is low.
- Diascopy during treatment of pigmented lesions reduces the risk of vascular damage.
- Longer-wavelength lasers allow for dermal pigmentation to be treated.
- Picosecond lasers can achieve optimal results in the treatment of nevus of Ota.
- Hori macules can be resistant to treatment, requiring multiple treatments. There is also a risk of initial darkening of pigmentation before subsequent lightening with further treatments.
- Melasma is a common pigmentary condition in ethnic skin and a challenge to

treat. Topical bleaching agents should be used before laser therapy is considered.

- Nonablative fractional resurfacing using lower densities but increasing number of treatment sessions is recommended for ethnic skin.

Introduction

The evolution of population demographics in the 21st century is such that patients with ethnic skin will become of increasing importance to any practicing dermatologist. Ethnic skin comprises a diverse group, including Chinese, Japanese, Indian, Pakistani, Hispanic, Latino, African, Afro-Caribbean, and African American. Their skin color typically falls within the Fitzpatrick's skin phototypes III to VI.

Ethnic skin differs from their white counterpart in several aspects. The larger melanocytes in skin of color produce more melanin, and melanosomes are distributed individually in keratinocytes, conferring significant photoprotection. Photoaging tends to manifest more frequently as pigmentary changes, as opposed to wrinkle formation. Congenital and acquired pigmentary disorders, such as nevus of Ota, Hori macules, and melasma are also more commonly encountered. Management of pigmentary conditions is therefore an important concern for most patients with ethnic skin. However, the high melanin content in such skin, coupled with the broad absorption of melanin on the electromagnetic spectrum, can often present therapeutic challenges during laser treatment, as a competing chromophore to the intended pigmented target is present throughout ethnic skin. Postinflammatory hyperpigmentation (PIH), rarely seen in light-colored skin, can be a common outcome during inexperienced laser use in darker skin types. This chapter aims to discuss the effective and safe use of laser and light sources in the management of common conditions seen in ethnic skin, to optimize results and minimize complications. We will also highlight good practices to adopt and pitfalls to avoid (Video 10.1 ▶).

Evaluating the patient with ethnic skin

A thorough history and examination is essential in establishing a correct diagnosis prior to treatment. Standardized digital photography is helpful in recording the baseline appearance and any subsequent improvement. Additional aids, such as Ultraviolet (UV) photography or Wood light can be useful, for example, in assessing the epidermal and dermal components of melasma. The patient's treatment objective and expectation should be inquired, and treatment options and associated risks discussed. Providing additional printed material regarding suggested procedures is often helpful. Obtaining informed consent prior to a procedure is essential and good practice. Establishing realistic patient expectations through good rapport is imperative in

achieving a satisfactory outcome.

A detailed patient interview can identify the patient's concern and highlight the primary problem, which must be addressed. For example, a patient presenting for management of acne PIH and scarring will require treatment for their active acne before embarking on treatment of the secondary complications. Any relative contraindications to laser and light treatment should be excluded, such as infection or recent sun exposure of the treatment site, recent intake of oral isotretinoin, photosensitivity or use of photosensitizing drugs, immunocompromised state, predisposition towards keloid or hypertrophic scarring, pregnancy, and personal or family history of melanoma. The patient's Fitzpatrick skin type should be noted.

Taking a thorough medical history also helps clinicians to identify patients who have unrealistic expectations or psychiatric disorders, such as body dysmorphic disorders (BDDs). Such patients have an excessive preoccupation with an imagined or slight defect in appearance, which results in clinically significant distress and impairment in functioning. A study reviewing 401 adults with BDD symptoms in an ethnically diverse group found significant differences between Asians and whites, with Asians reporting more concerns with straight hair and dark skin, and less concerns about body shape. A simple and reliable questionnaire for the diagnosis of BDD has been developed and can be a useful adjunct in suspected cases. BDD is a contraindication to laser treatments, and these patients should be referred for psychiatric and psychotherapeutic treatments.

Obtaining written consent with a clear outline of risks and benefits is essential and protects both the clinician and the patient. The clinician should ensure that patients have a good understanding of different treatment options, the expected outcome, the associated downtime, postoperative care, and potential risks from the procedure. There should be adequate opportunity for the patient to have all their questions answered.

Any sun exposure during several weeks prior to laser treatment can predispose patients with ethnic skin to a higher risk of post-inflammatory hyperpigmentation or hypopigmentation. The use of sunscreens and topical bleaching agents for at least 2 weeks prior to any such treatment can help to reduce the risk of PIH. Patients should be provided written guidance regarding postoperative care, with additional emphasis on sun protection and avoidance for at least 4 weeks after.

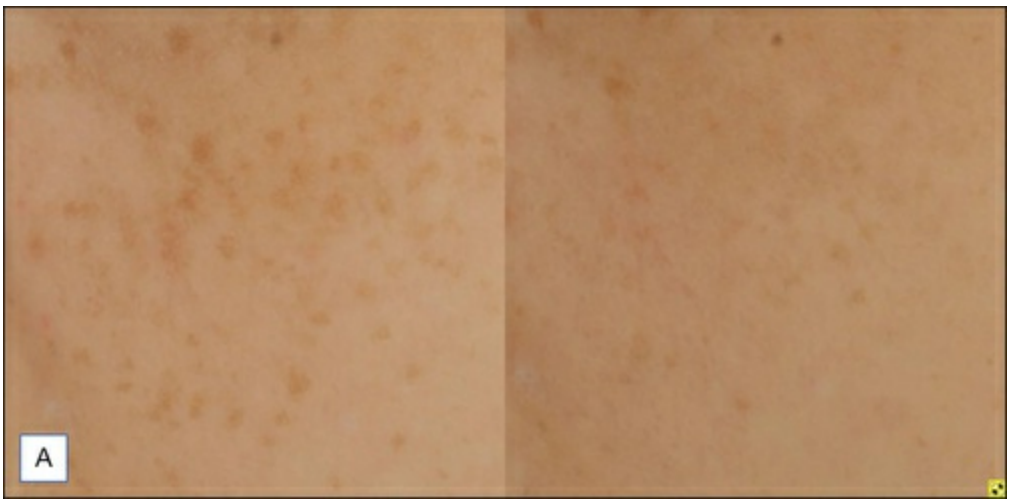
Treatment of epidermal pigmentation

Freckles and lentigines

Freckles and lentigines are benign pigmented lesions commonly seen in ethnic skin. Freckles occur in adolescence and are relatively uniform in distribution, size, and color. Histologically they are characterized by epidermal hypermelanosis without an increase in melanocyte numbers. Lentigines tend to appear later and vary in size, color, and distribution. Histologically both

epidermal hypermelanosis and increase in melanocyte numbers are seen. Epidermal rete ridges are also elongated and clubbed.

Because melanin has a broad absorption spectrum ranging from 250 to 1200 nm, various lasers have been used to target cutaneous pigmentation, usually with excellent results. Anderson et al. were the first to demonstrate the effectiveness of Q-switched (QS) lasers in the treatment of cutaneous pigmentation. Frequency-doubled QS neodymium:yttrium-aluminum-garnet (Nd:YAG), QS ruby, and QS alexandrite lasers with respective wavelengths of 532, 694, and 755 nm, have all been used with good results in lighter-skinned patients, but PIH risk of 10% to 25% has been reported when used on ethnic skin. Chan et al. later compared 532-nm, frequency-doubled Nd:YAG lasers with different pulse durations in the treatment of facial lentigines in Chinese patients and found similar efficacy between QS Nd:YAG and long-pulsed (LP) potassium titanyl phosphate (KTP) but a higher risk of postoperative hyperpigmentation with the QS device. A study comparing QS and LP alexandrite for the treatment of freckles and lentigines in 20 Chinese patients showed similar results (Fig. 10.1). There was significant improvement in pigmentation in both groups, with no difference between the groups. However, the risk of PIH was 22% in the QS group, compared with 6% in the LP group. Patients also complained of more severe pain, erythema, and edema with the QS device. These findings were further validated in a retrospective study, comparing treatment of lentigines in 40 Chinese patients with four different devices; 595-nm long-pulsed dye laser (LPDL), 755-nm alexandrite laser, 532-nm QS Nd:YAG, and 532-nm LP KTP laser (Fig. 10.2). The results showed that an LP laser and small spot size appear to reduce the risk of PIH in darker skin types (Case Study 1).



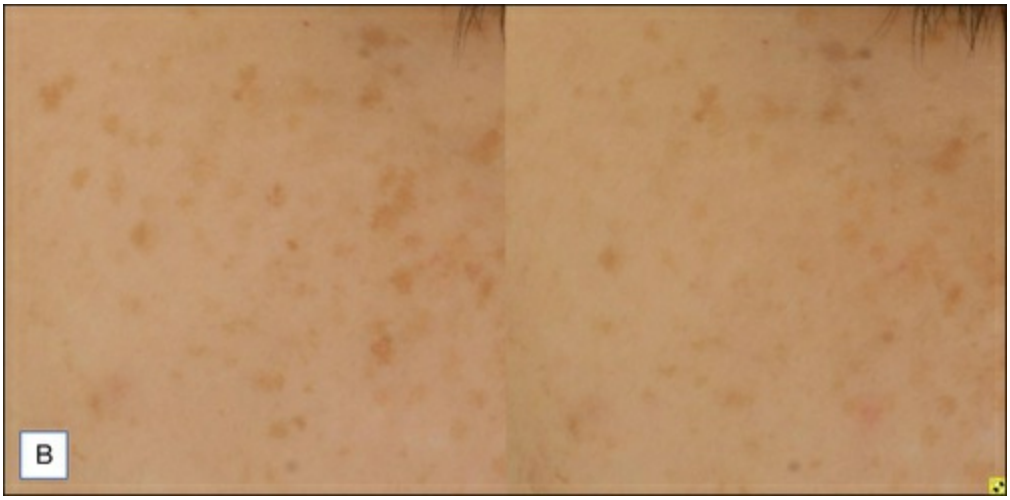
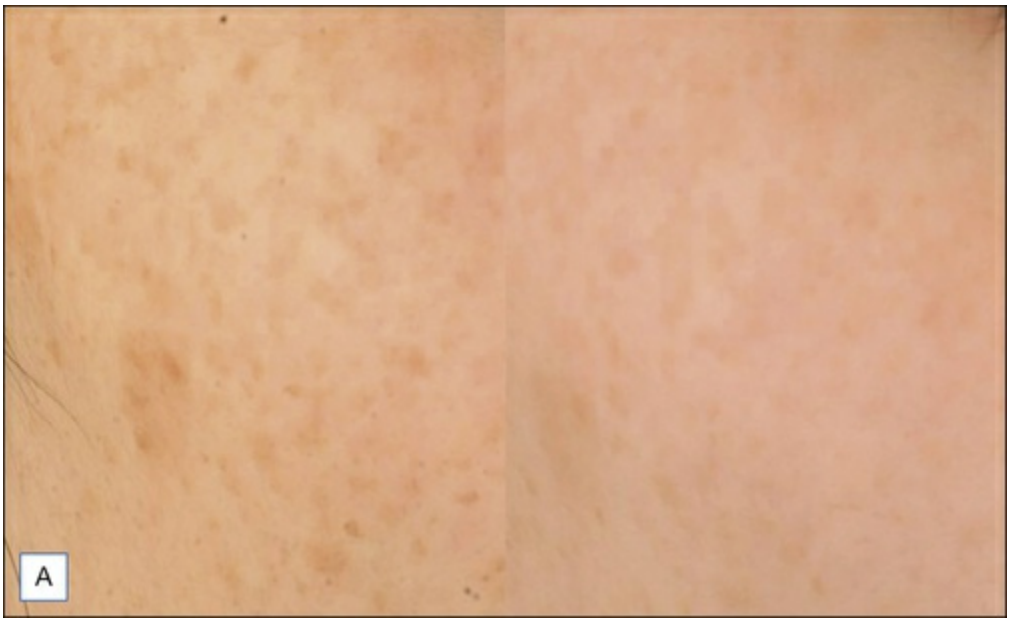


FIGURE 10.1 Representative clinical responses to the two laser treatments. (**A**) Three months post treatment with QS alexandrite laser; treatment parameters: 3 mm, 5 J/cm^2, 2 Hz. (**B**) Three months post treatment with LP alexandrite laser; treatment parameters: 4 mm, 13 J/cm^2, 2 Hz.



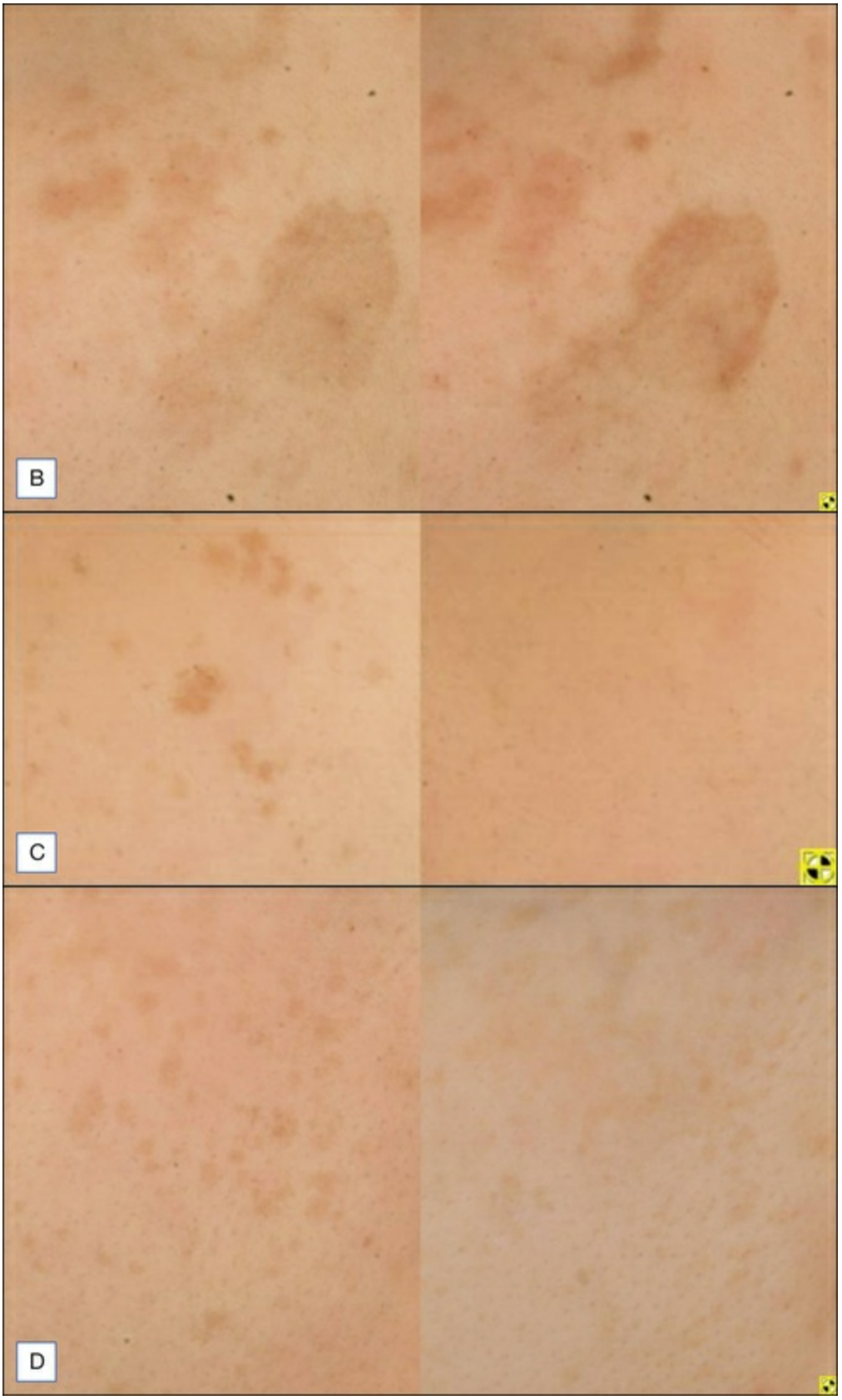


FIGURE 10.2 Management of freckles and lentigines with different pigment-specific lasers. (**A**) Marked improvement after two treatments with 595-nm LPDL; treatment parameters: 7 J/cm^2, 10 mm, 6 ms, cooling 3. (**B**) PIH post single LP alexandrite laser treatment; treatment parameters: 25 J/cm^2, 1.5 Hz, 3 × 10 mm,

DCD 0/20/0, 3 ms. (**C**) After three treatments with LP 532-nm Nd:YAG; treatment parameters: 2 mm, 13 J/cm^2, 2 ms, 1 Hz. (**D**) After three treatments with LP 532-nm Nd:YAG; treatment parameters: 2 mm, 13 J/cm^2, 2 ms, 1 Hz.

Case Study 1

Freckles and Lentigo (Fig. 10.18A and B)

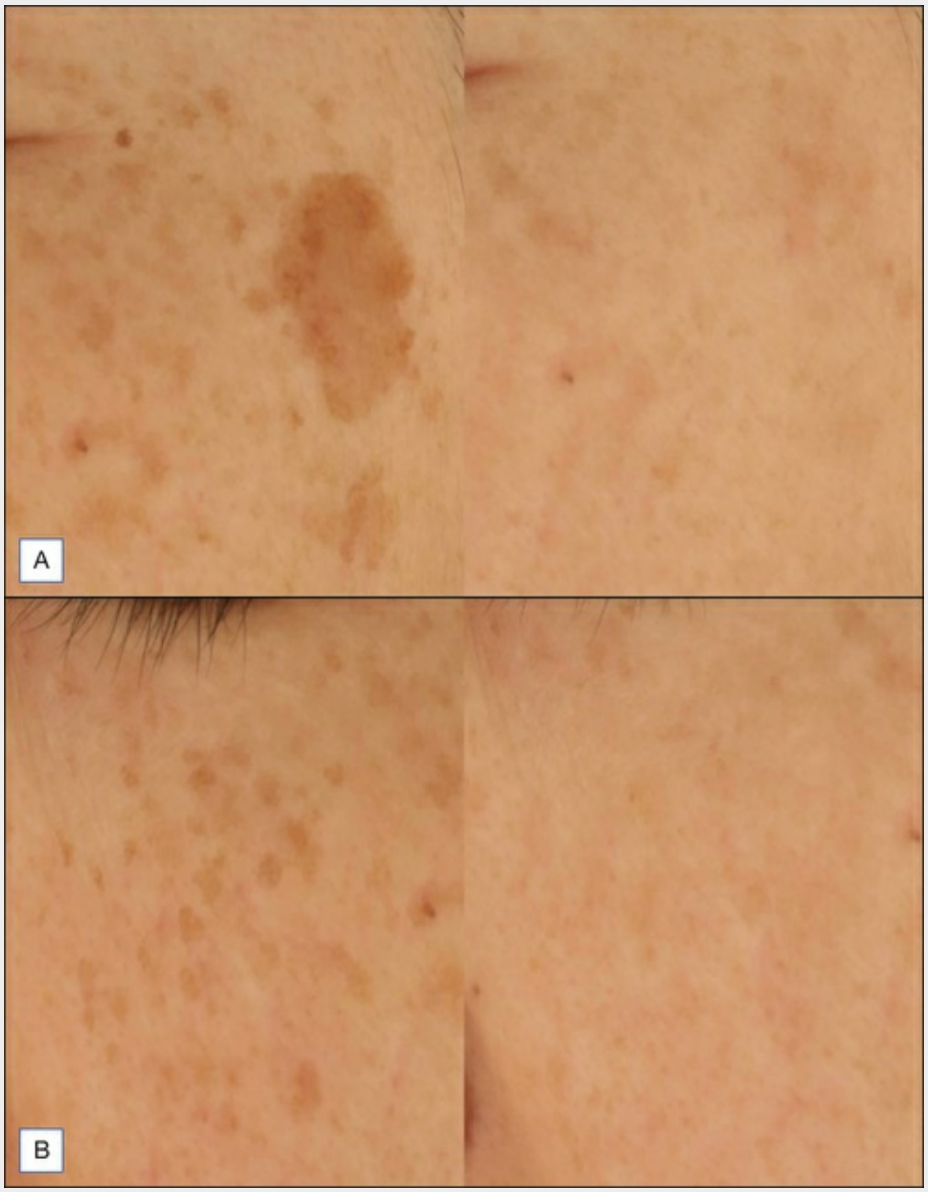


FIGURE 10.18 (**A**) Lentigo and (**B**) freckle showing improvement in epidermal pigmentation after treatment with the LP 532-nm laser.

A 55-year-old female who enjoys outdoor activities and sunbathing presents with troubling pigmentation on her face, which has been increasing in numbers in recent years. She does not use sunscreens and continues to play

golf on a regular basis. She has a busy job that requires her to meet with clients on a daily basis and requests a treatment with little downtime.

Examination reveals type III skin with multiple freckles on both cheeks and a large lentigo over her left zygoma. Different pigment laser options were discussed with the patient. The importance of sun avoidance 2 weeks before and after treatment was emphasized.

Because she wants an effective treatment with a low risk of PIH, the LP KTP 532-nm laser (10.5–11 J/cm^2, 3-mm spot size, pulse duration 2 ms) was used to target her unwanted epidermal pigmentation. She showed good improvement after two treatment sessions. She was given the appropriate sun protection advice and prescribed daily sunscreen. Further treatment sessions can be considered if further lightening of her pigmentation is required.

LP lasers, with their longer millisecond pulse width, result in more absorption by target melanin and less absorption by competing chromophores, such as oxyhemoglobin, and surrounding pigment-laden skin. This is particularly important in reducing the risk of PIH in ethnic skin. The postulated reason is that LP lasers cause melanin destruction by photothermolysis only. In contrast, QS lasers emit high-energy, nanosecond radiation, causing both photothermal and photomechanical effects. Not only is the target pigmented lesion destroyed by the short burst of intense radiation, surrounding melanin and oxyhemoglobin are also damaged, resulting in altered activity of melanocytes, hemosiderin deposition from damaged vessels, and subsequent PIH.

Spot sizes are also an important consideration when treating darker skin types. From our retrospective study comparing the four different laser devices mentioned earlier, we noted that when using LP alexandrite in the treatment of epidermal pigmentation in Asian skin, despite its long pulse width, significant improvement in lesional pigmentation was not found and was associated with the highest risk of PIH (20%). We postulated that the large spot size (10 mm) in the LP alexandrite laser may have led to inadvertent treatment of surrounding unaffected skin, when the lesion treated is smaller than the spot size available, and this is especially pertinent in ethnic skin where contrast between the lesional and nonlesional skin is low.

There is increasing evidence to support the use of diascopy during laser treatment to reduce the risk of PIH. This is especially true when using pigment lasers that target both oxyhemoglobin and melanin, such as the LPDL. Compression of the skin surface by the flat glass window on the handpiece leads to emptying of blood vessels, reducing the risk of vascular damage, and subsequent purpura, hemosiderin deposition, and PIH. The effectiveness of such simple diascopy is supported by results from studies carried out by Kono et al., who conducted three different studies using 595-nm LPDL, repeatedly demonstrating its effectiveness and safety when used with compression for the treatment of lentigines in ethnic skin, when compared with IPL and QS ruby laser. Our retrospective study also showed that 595-nm LPDL and 532-nm LP KTP, both of which use a compression window, have better results and fewer

complications compared with 532-nm QS Nd:YAG and 755-nm LP alexandrite laser.

Intense pulsed-light (IPL) sources emit a broadband of visible light (400 to 1200 nm) from a noncoherent filtered flashlamp and target melanin through photothermal effects. Negishi et al. carried out two studies looking at photorejuvenation using IPL. Results from the first study involving 97 Asian patients showed that more than 90% reported a reduction in pigmentation after three to six treatments at intervals of 2 to 3 weeks (cutoff filter 550 nm, 28 to 32 J/cm^2, double pulse mode of 2.5 to 4.0/4.0 to 5.0 ms, delay time 20/40 ms). The second study used IPL with an integrated cooling system and found 80% of the 73 patients had a significant reduction in pigmentation after three to five treatments at intervals of 3 to 4 weeks (cutoff filter 560 nm, 23 to 27 J/cm^2, double pulse mode of 2.8 to 3.2/6.0 ms, delay time 20/40 ms). Kawada et al. also treated lentigines and freckles in 60 patients with IPL and reported more than 50% improvement in 68% of these patients after three to five treatments at intervals of 2 to 3 weeks. No PIH was reported in any of these studies. A further split-face study comparing QS alexandrite and IPL for freckles and lentigines in Asians found significant improvement with the QS device. However, the risk of PIH was also higher with the QS device, especially in patients with lentigines. No PIH was seen in the IPL group. These studies serve to highlight IPL, through photothermal effects, is effective and safe in the treatment of epidermal pigmentation in ethnic skin. However, multiple treatments are required. Furthermore, with a large spot size, if the contrast between the lesional and nonlesional skin is low, the therapeutic window is much narrower. Either the operator uses suboptimal energy, leading to minimal effectiveness, or above-threshold energy that may lead to greater risk of injury to surrounding normal skin.

Pearl 1

When the contrast between lesional and nonlesional skin is low, a small spot size allows treatment of lesions without inadvertent injury to surrounding normal skin.

Pearl 2

LP lasers are associated with fewer complications than QS lasers but require more treatment sessions.

In 2012 the US Food and Drug Administration (FDA) cleared picosecond lasers for the removal of tattoos. More recently, picosecond lasers have gained popularity for the treatment of other benign pigmented lesions (see Chapter 3). Picosecond lasers can also be used for the treatment of lentigines in dark skin, and although it certainly can be effective, the risk of PIH remains and, in our unpublished data, the risk is approximately 5%. Given the current cost effectiveness, picoseconds lasers do not offer an advantage over other devices

for such types of lesions (Fig. 10.3).

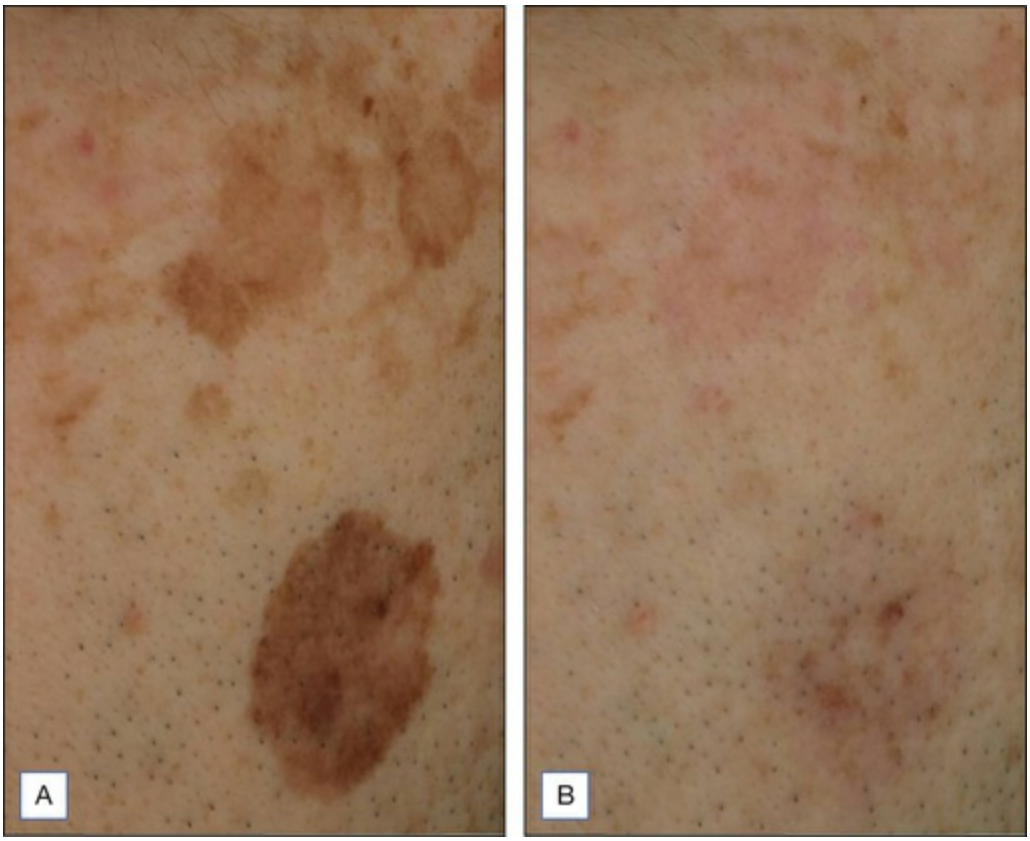


FIGURE 10.3 (**A**) Lentigines at baseline and (**B**) 1 week after three treatments with 750 ps QS 532-nm Nd:YAG laser; treatment parameters: 0.4 J/cm^2, 2 Hz, 4 mm.

A treatment algorithm for epidermal pigmentation is as follows:

1. IPL can be recommended for patients who are intolerant of any PIH risk and are amenable to having several treatment sessions.

2. LP lasers are effective, yet require fewer treatments than IPL, and carry a low PIH risk.

The more aggressive approach using QS lasers requires only one to two sessions but carries the highest risk of PIH and downtime of a week. This should be reserved for patients with time and cost constraints. A picosecond laser can also be used for the treatment of freckles and lentigines, and similar to QS laser treatment, only one to two treatments are required. We observe a PIH rate of approximately 5%. Therefore, in the authors' opinion, picosecond lasers do not offer a distinct advantage over QS lasers for the treatment of these benign pigmented lesions.

Treatment of dermal pigmentation

Dermal pigmentation, such as nevus of Ota and acquired bilateral nevus of Ota-like macules (ABNOM) or Hori macules, is much more commonly encountered in ethnic skin. Removal of unwanted tattoos and hair requires the removal of dermal pigment. In such conditions, devices with longer wavelengths, and hence deeper penetration, are used to provide enhanced clearance.

Nevus of Ota

Nevus of Ota is an oculodermal melanocytosis affecting approximately 0.6% of the Asian population at birth or developing in their teens. Clinically it presents as a bluish-black hyperpigmentation along the ophthalmic or maxillary branches of the trigeminal nerve. QS lasers, including QS ruby, QS alexandrite, and QS 1064-nm Nd:YAG have all been used to achieve good therapeutic results. Watanabe and Takahashi looked at 114 nevus of Ota patients treated with QS ruby and reported a good-to-excellent degree of lightening after three or more sessions. Kono et al. confirmed the findings when he reviewed 101 nevus of Ota patients treated with QS ruby and reported 56% achieving 75% improvement, and 36% achieving complete clearing. Hypopigmentation was seen in 17% of patients and hyperpigmentation in 6%. Studies comparing the use of QS alexandrite and QS 1064-nm Nd:YAG found the former better tolerated but the latter more effective after three or more treatment sessions. The longer wavelength of the QS Nd:YAG targets dermal pigment effectively with minimal epidermal damage in darker-skinned individuals. More recently, fractionated laser technology has been added to the currently available options. Near-complete clearance of a case of nevus of Ota after serial therapy using 1064-nm QS Nd:YAG, followed by 1550-nm nonablative fractionated erbium-doped fiber laser treatments at 2-month intervals; and a further case achieving complete clearance with sequential same-day therapy with the same devices have been reported. Treatment of nevus of Ota at a younger age requires fewer treatment sessions and is associated with fewer complications compared with older patients, and early treatment is therefore recommended. It is important to note that the risk of recurrence is estimated to be between 0.6% and 1.2%, which has important implications, particularly when counseling pediatric patients.

More recently, picosecond lasers have been used for the treatment of nevus of Ota. In our retrospective study a picosecond Alexandrite laser can achieve excellent to complete clearance in three to four treatment sessions, with few complications. Although our series was small, such preliminary data are promising because it is important to minimize the number of treatments that require sedation for young children. It is now our routine practice to use such a laser for the treatment of nevus of Ota (Fig. 10.4) (Case Study 2).

Pearl 3

Patients seeking treatment for nevus of Ota should be treated at an earlier age

to reduce the risk of complications and also to reduce the number of treatment sessions required. Picosecond lasers are rapidly becoming the preferred laser for treatment.

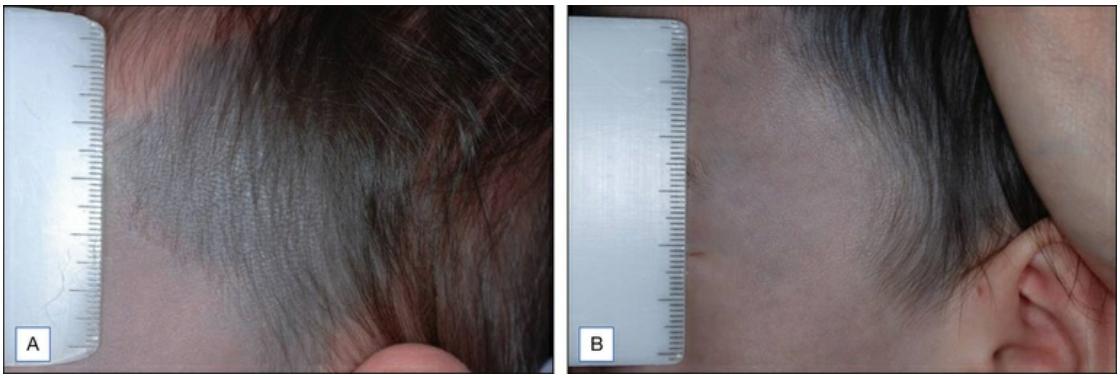


FIGURE 10.4 (**A**) Nevus of Ota at baseline and (**B**) 6 months after three treatments with picosecond alexandrite laser; treatment parameters: 755 nm, 1.26 to 2.49 J/cm^2, 2.5 Hz, 3.2 to 4.5 mm.

Case Study 2

Nevus of Ota (Fig. 10.19)

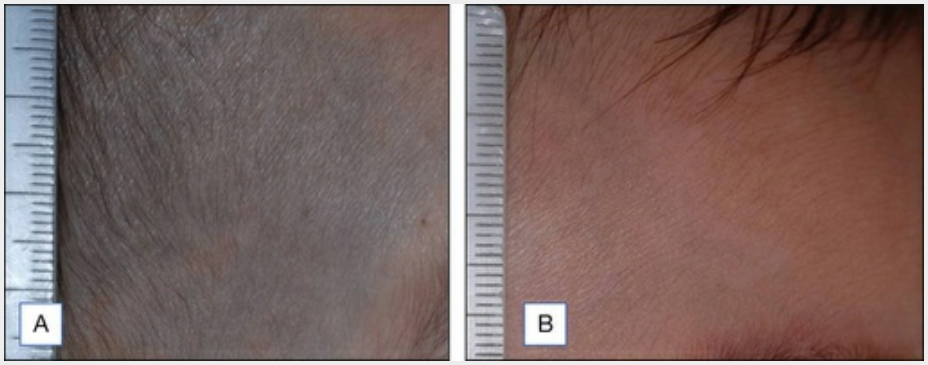


FIGURE 10.19 (**A**) Nevus of Ota at baseline and (**B**) after three treatments with picosecond alexandrite laser; treatment parameters: 755 nm, 2.08 to 3.77 J/cm^2, 2.5 to 5 Hz, 2.5 to 3.5 mm.

A 9-month-old female presented with a 6 × 4 cm bluish hyperpigmented patch affecting her right temporal area. The diagnosis of nevus of Ota was made. She was first treated with QS ruby 694-nm laser (2–2.5 J/cm^2, 2 Hz, 5 mm) at 1-month intervals with limited clinical improvement. Picosecond alexandrite laser (755 nm, 2.08–3.77 J/cm^2, 2.5-5 Hz, 2.5-3.5 mm) was then used and after three treatments delivered at 1- to 3-month intervals her lesion significantly improved to almost complete clearance. No complications were reported.

Hori macules or acquired bilateral nevus of Ota-like macules

Hori macules (ABNOM) affect 0.8% of the Asian population and present in late adulthood as bluish-brown dermal hyperpigmentation typically affecting the bilateral malar regions, forehead, and temples of middle-aged women, without any mucosal involvement. QS lasers, such as QS ruby, QS alexandrite, and QS 1064-nm Nd:YAG have been found to be effective in the treatment of Hori macules. More recent studies also support these results. Kagami et al. reported the efficacy of QS alexandrite in 24 Japanese patients, with 45.8% reporting greater than 50% improvement. Cho et al. also evaluated the use of 1064-nm QS Nd:YAG at low fluences in 15 patients, 80% of whom had greater than 50% improvement. From our experience, Hori macules tend to be more resistant to treatment than nevi of Ota. Shorter treatment intervals every 4 weeks tend to yield better results. Combination treatment with QS 532-nm Nd:YAG, followed by QS 1064-nm Nd:YAG has also been found to be more effective than the 1064-nm wavelength alone. Transient PIH is a common adverse event, occurring in the majority of treated patients (Fig. 10.5). Permanent hypopigmentation has been reported after QS ruby treatment. To reduce the risk of PIH, all patients should be given pretreatment and posttreatment bleaching agents (Case Study 3). Picosecond lasers have also been used with similar success as seen with QS lasers.

Pearl 4

Hori macules require multiple treatment sessions to yield improvement. Warn patients that initial deterioration can occur and can be treated with bleaching agents.

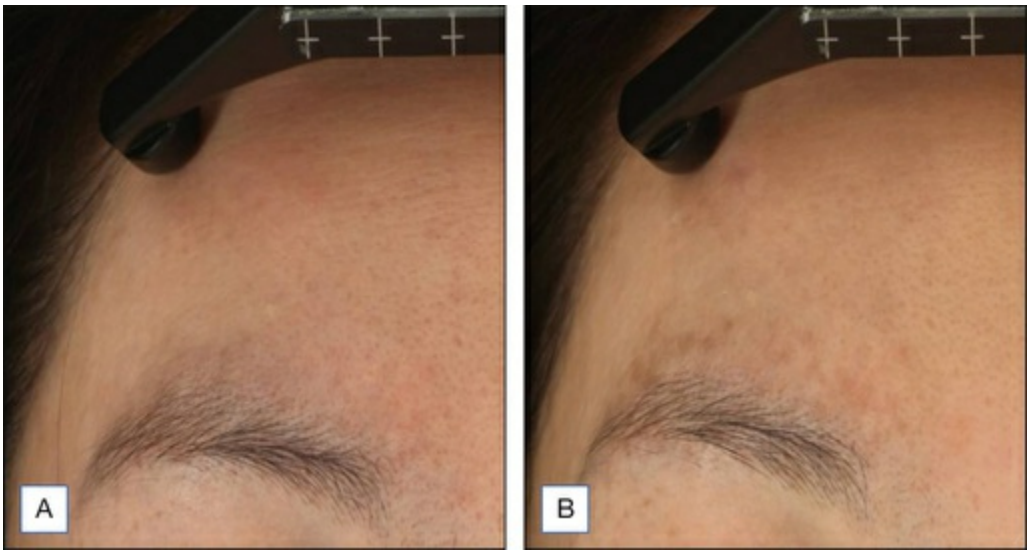


FIGURE 10.5 (**A**) Hori macules before QS ruby treatment and (**B**) PIH post QS ruby treatment.

Case Study 3

Hori Macules (Fig. 10.20)



FIGURE 10.20 Lightening of Hori macules after treatment with QS ruby laser and QS alexandrite 755-nm laser.

A 28-year-old Chinese female presents with speckled dark pigmentation over her malar cheeks. She noticed this only in the past 2 years and worries that it may darken further. She does not use regular sunscreen.

Examination confirmed the presence of Hori macules on both malar cheeks. There was no mucosal involvement. A discussion with the patient explored treatment options, and it was explained that several laser treatments are required for this resistant dermal condition. The risk of hyperpigmentation after initial laser treatment before subsequent lightening after further treatment was highlighted. She consented and underwent three sessions of QS ruby laser (3.4 J/cm^2, long tip 5 mm) and a further session with QS alexandrite 755-nm laser (8.5 J/cm^2, 3 mm). Bleaching topical agents were used in between treatments. She achieved and maintained significant lightening 3 months after her last treatment.

Tattoo removal

The removal of unwanted tattoos without scarring is now possible even in dark-skinned individuals. Because different inks are present in any one tattoo, effective treatment may require the use of various wavelengths and entail multiple treatments. QS lasers are effective in removing black and blue tattoos. The longer wavelengths, such as the 1064-nm QS Nd:YAG or 755-nm alexandrite laser, are better suited to tattoo removal of darkly pigmented skin because there is less absorption by epidermal melanin and a reduced risk of subsequent dyspigmentation. Conservative initial treatment with low fluences (e.g., 1064-nm Nd:YAG, 4-mm spot size, 2.0 to 2.6 J/cm^2) is recommended, until the end point of whitening with no punctuate bleeding is achieved. The 694-nm

QS ruby laser, although effective, can result in hyperpigmentation or permanent hypopigmentation of the skin.

Picosecond lasers offer a distinct advantage over nanosecond lasers in the treatment of tattoos because the shorter pulse duration generates a greater photomechanical effect as compared with a nanosecond laser. The short pulse duration allows any photothermal effect to be confined to tattoo ink, the thermal relaxation time of which is often in the picosecond domain. In our experience, for skin of color, the treatment parameters need to be more conservative, aiming for the lowest fluence to cause immediate whitening. To prevent blister formation, it is our practice to use nonablative fractional resurfacing (NA FR), immediately after laser tattoo removal. It is thought that focused columns of thermal injury in the areas of the tattoo-treated skin may help to prevent large blister formation. Ablative fractional resurfacing (AFR) is likely to be more effective for such purposes but carries a higher risk (Fig. 10.6).[1]

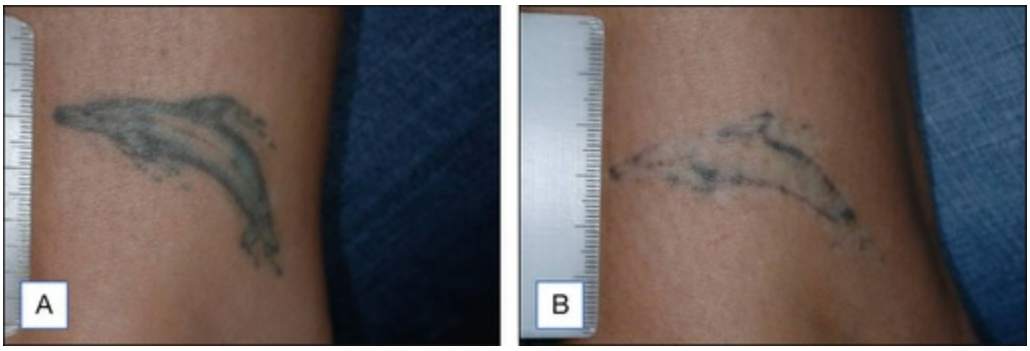


FIGURE 10.6 (**A**) Tattoo removal at baseline and (**B**) after single treatment with picosecond alexandrite laser; treatment parameters: 755 nm, 1.86 J/cm^2, 2.5 Hz, 3.7 mm.

Hair removal

Pigment-specific lasers with longer wavelengths, longer pulse durations, and concomitant epidermal cooling have been successfully used for hair removal in darkly pigmented skin. LP alexandrite laser, 810-nm diode, and 1064-nm Nd:YAG lasers can all be safely applied with few side effects. A split-axilla comparison study showed that, although both high-fluence, low-repetition 1064-nm Nd:YAG and low-fluence, high-repetition 810-nm diode lasers were successful in axillary hair removal, results with the Nd:YAG were better. However, the diode laser was less painful. The use of pneumatic skin flattening has also been explored as a viable alternative to dynamic cooling device, in the reduction of pain during axillary hair removal.

Treatment of dermoepidermal pigmentation

Common conditions where melanin is found in dermoepidermal locations

include Becker nevus, melasma, PIH, and melanocytic nevi.

Becker nevus

Becker nevus commonly presents as a brown, irregular patch accompanied by dark, coarse hair. It usually appears in adolescence and in males. Histologically, increased melanin is seen in the basal cells, and melanophages may be present in the papillary dermis. It is a benign condition with no reports of malignant transformation. Previously, lasers, such as QS ruby and QS Nd:YAG, have been shown to improve such lesions. A comparative study of the two devices showed mean clearance of at least 43% after a single treatment with either laser. Trelles et al. later compared the use of erbium-doped yttrium-aluminum-garnet (Er:YAG) laser and QS 1064-nm Nd:YAG in 22 patients. At 2-year follow-up, 54% of patients (n = 6) achieved complete clearance after a single treatment with Er:YAG, compared with only one out of 11 patients reporting clearance after three treatment sessions of Nd:YAG laser. Although clinically effective, ablative laser carries a high risk of adverse effects, especially in darker skin types. QS lasers rarely achieve complete clearance, and multiple treatments are necessary. More recently, fractional resurfacing has been suggested as a promising new treatment modality, with two cases reporting at least 75% pigment reduction after five to six treatments with 1550-nm erbium-doped fiber laser at 4-week intervals. LP pigment lasers have also been used successfully to target both pigment and hair in Becker nevus. In our experience, LP alexandrite (20 to 35 J/cm^2, 10-mm spot size, pulse duration 1.5 ms) gives a 50% success rate after four to eight treatments. Possible side effects include scarring and hypopigmentation. LP pigment laser together with NA FR with 1927-nm thulium fiber laser can lead to an optimal outcome (Case Study 4).

Case Study 4

Becker Nevus (Fig. 10.21)



FIGURE 10.21 Improvement in Becker nevus after treatment with LP alexandrite laser and nonablative fractional resurfacing with 1927-nm thulium fiber laser.

A 27-year-old male developed a hairy pigmented area on his left jaw during his teens and presented requesting its removal. It has not changed in size or darkened in recent years, but he is highly troubled by its cosmetic appearance.

Examination showed a large irregular brown patch with several dark hairs over his left jaw. A Becker nevus was diagnosed, and the patient was treated with LP alexandrite laser (20–30 J/cm^2, 10-mm spot size, pulse duration 1.5 ms). He underwent four treatments at 4- to 6-week intervals. He also underwent two sessions of nonablative fractional resurfacing with a 1927-nm thulium fiber laser (treatment level 11, eight passes) to achieve further improvement. A faint brown patch remains and the patient is satisfied with the improvement in appearance.

We have also tried picosecond lasers for more resistant cases of Becker nevi, and although some success can be achieved, lack of complete clearance and recurrence remain as limitations to treatment (Fig. 10.7).

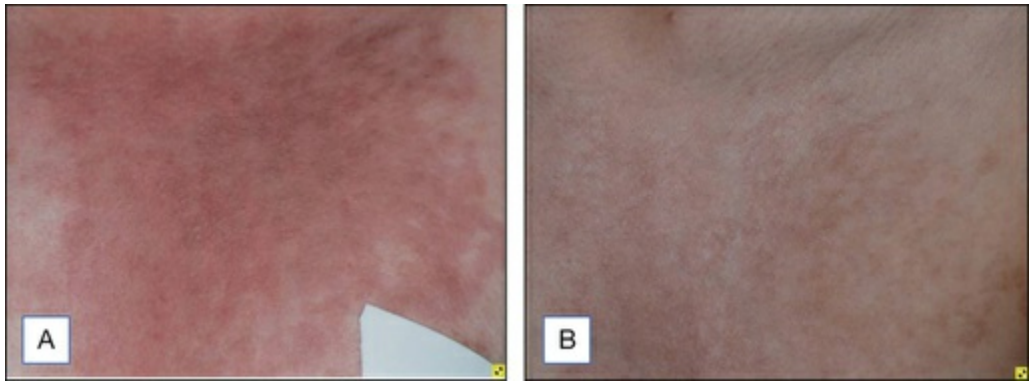


FIGURE 10.7 (**A**) Becker nevus at baseline and (**B**) after three

treatments with picosecond laser; treatment parameters: 755 nm, 2.08 to 3.49 J/cm^2, 2.5 Hz, 2.7 to 3 mm.

Melasma

Melasma is a common acquired symmetrical hypermelanosis involving sun-exposed areas, commonly seen in Asian middle-aged women. Genetics, UV radiation, pregnancy, and hormonal therapies are all thought to be contributing etiologic factors, and it remains a challenging condition to treat. Increased pigment can be seen in either the epidermis (brownish black), dermis (bluish gray), or both. There may also be some overlap between dermal melasma and Hori macules (ABNOM). A Wood lamp can be useful in differentiating between the skin layers, with the pigmented epidermal layer demonstrating increased reflectance, in contrast to a lack of reflectance from the pigmented dermal layer.

In addition to sun protection and avoidance of aggravating factors, such as oral contraceptives, bleaching agents remain the mainstay of treatment for melasma. Combinations of hydroquinone with topical corticosteroids and tretinoin are effective as first-line treatment. Other bleaching agents used include azelaic acid, kojic acid, arbutin, and licorice extract. Their mechanism of action includes tyrosinase inhibition, suppression of the secretory function of melanocytes, decreasing rate of transfer of melanin from melanosomes to keratinocytes, and increased epidermal turnover. Chemical peels and microdermabrasion are also useful adjuncts to topical treatments in the management of melasma in Asians.

Although laser therapy has been used to improve melasma, caution must be exercised because worsening of the disease or PIH may occur after treatment. This is likely to be due to the pathogenesis of melasma, which is believed to be due to increased activity of melanogenic enzymes, resulting in hyperactive melanocytes. Sublethal laser damage to these labile melanocytes is thought to result in an increase in melanin production and hyperpigmentation. Laser therapy should therefore be considered as second-line treatment for patients who have not improved sufficiently after 3 to 6 months of topical treatment.

Wang's group in Taipei examined patients with melasma treated with IPL and found a significant improvement of 39.8% in the IPL group, compared with 11.6% in the control. Two patients developed transient PIH, and partial repigmentation was noted after 24 weeks, suggesting the need for repeated treatments for maintenance. They suggested the lowest fluence to achieve minimal erythema be used, which supported findings by Negishi's group. This is to avoid excessive thermal damage to labile melanocytes, which may lead to inflammation and subsequent PIH.

Pigment lasers have also been used to treat melasma. Low fluence, large spot size, multiple pass QS 1064-nm Nd:YAG, sometimes referred to as laser toning or laser facial, has become increasingly popular for the treatment of melasma. Some studies have reported it to be effective and safe, whereas others have highlighted important complications. Zhou et al. published a study examining

50 patients with melasma treated with nine weekly sessions and reported 70% with more than 50% reduction in Melasma Area and Severity Index (MASI) values and 10% with complete clearance. However, the recurrence rate at 3 months was 64%. Promising results were similarly reported in a prospective study by Polnikorn, after 10 weekly sessions of 1064-nm Nd:YAG in 35 refractory melasma cases. Recurrence at 6 months was seen in two cases. In addition, he noted mottled hypopigmentation occurring in three patients. Facial depigmentation is an increasingly recognized phenomenon often encountered with frequent treatments with QS 1064-nm Nd:YAG (Fig. 10.8). Chan et al. reported it in 14 Chinese patients, after a variable number of such treatments. Wattanakrai et al. and Cho et al. also described a similar adverse effect occurring after 1 to 2 weekly treatments with this laser for melasma, with 13.6% and 8% rates of hypopigmentation reported, respectively. With risks of recurrence and punctuate hypopigmentation post-laser treatment, patients need to be adequately informed of potential complications prior to embarking on such treatments for melasma. Optimal parameters from future studies will be helpful and lower fluence together with microdermabrasion has been demonstrated to be effective with lower side effect profile.

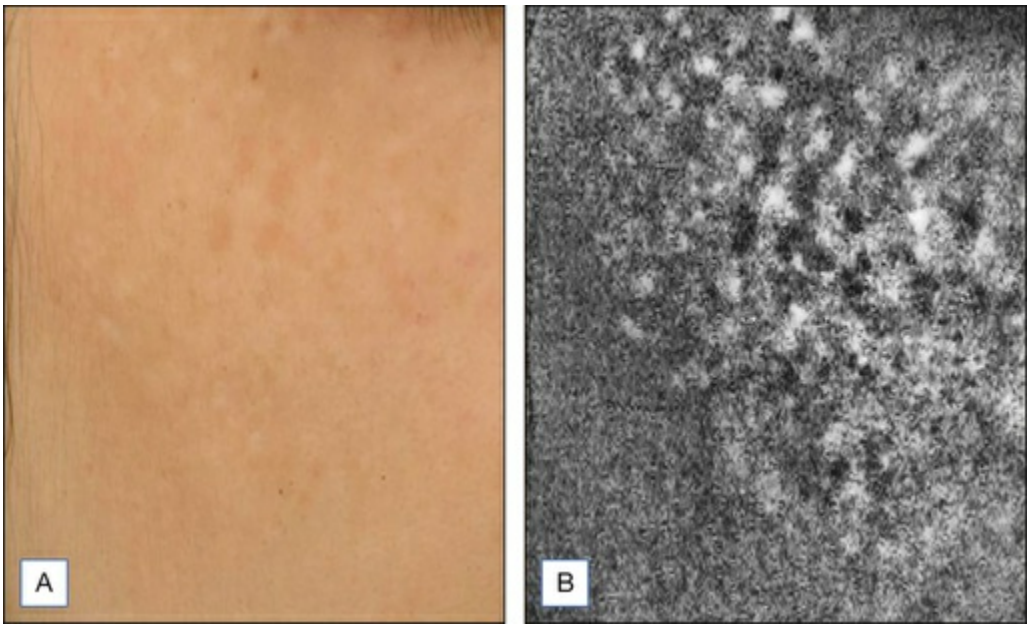


FIGURE 10.8 (**A**) Cross-polarized and (**B**) UV images of depigmented macules after 20 sessions of QS 1064-nm Nd:YAG laser treatment.

Ablative resurfacing has been used with some success for the treatment of melasma. A Thai study showed promising results using variable square pulse Er:YAG laser resurfacing in 20 patients. However, 17.6% experienced transient PIH, and recurrence was observed after the treatment was discontinued. Fractional resurfacing has been explored as a better option, with "melanin shuttling" of underlying dermal pigment coupled with remodeling of the

underlying pathologic dermis proposed as a possible mechanism. Rokhsar and Fitzpatrick piloted the use of fractional resurfacing in 10 patients and demonstrated 60% achieved 75% to 100% improvement, and 30% had less than 25% improvement when treated at 1 to 2 week intervals for four to six treatments. A Korean study later showed more limited efficacy, with 60% of 25 patients reporting improvement in melasma after four monthly sessions and improvement declining to 52.2% at 6 months; 13% of patients developed hyperpigmentation (Fig. 10.9).

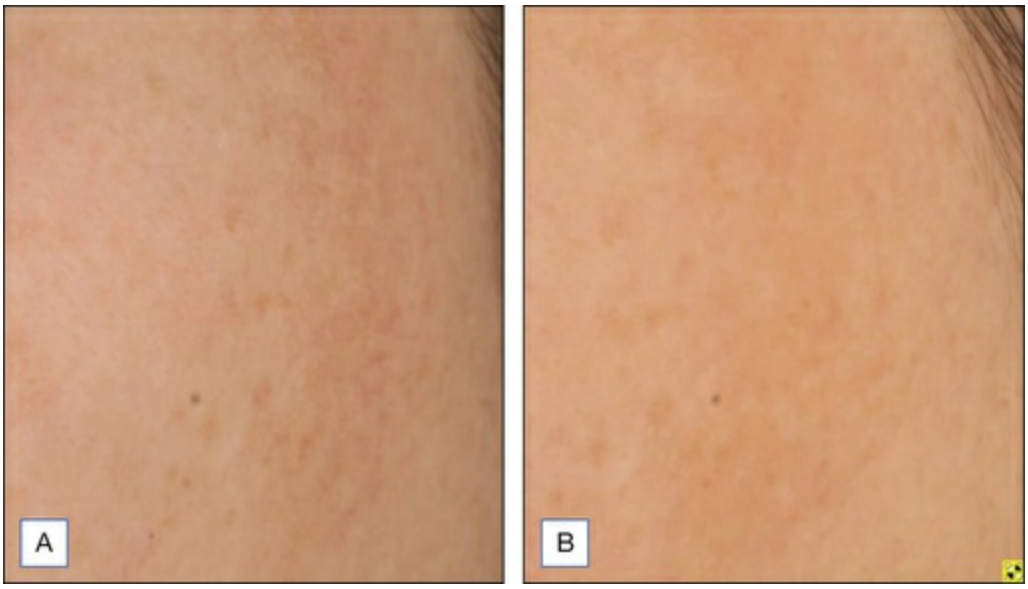


FIGURE 10.9 (**A**) Melasma before picosecond fractional laser and (**B**) 2 months after a single treatment; treatment parameter: 0.7 J/cm^2, 10 Hz, 6 mm.

Due to limitations of recurrence, hyperpigmentation and hypopigmentation post-laser treatment, topical treatments remain the first-line treatment for melasma, and laser treatment should only be used with caution, especially in ethnic skin.

Pearl 5

Treatment with low-fluence, large spot size QS 1064-nm laser can improve melasma. However, mottled hypopigmentation can occur after repeated treatment in approximately 10% of patients.

Pearl 6

Laser and IPL should be considered as second-line treatment for patients with melasma because there are risks of hyperpigmentation and hypopigmentation, as well as recurrence.

Picosecond lasers with or without fractionated delivery have also been used

with some success for the treatment of melasma. However, to date, no long-term studies are available to suggest they can provide a more durable clinical outcome as compared with other laser- and light-based technology (Fig. 10.10).

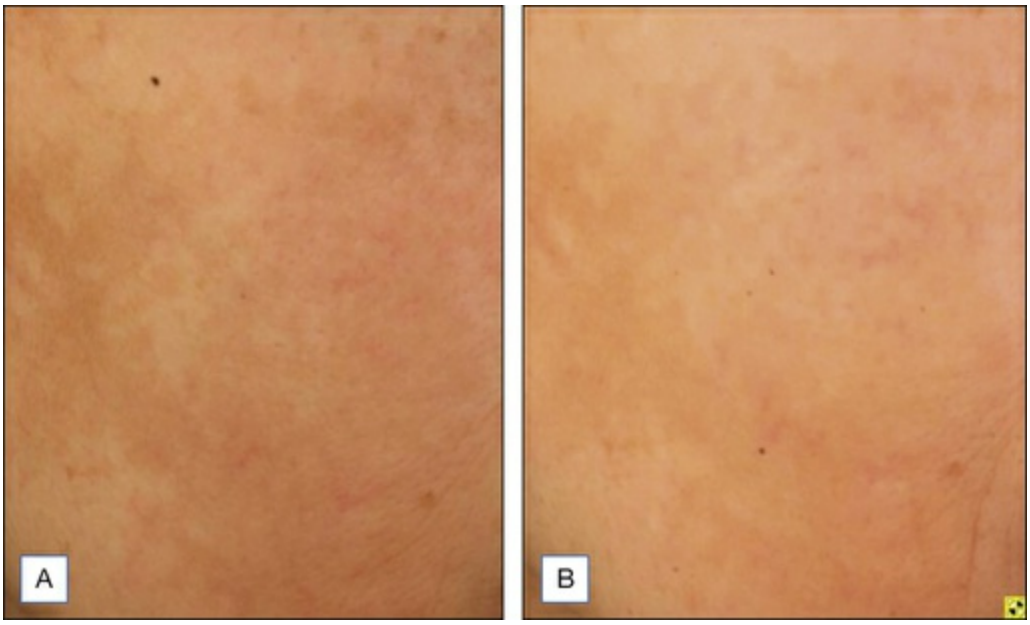


FIGURE 10.10 (**A**) Melasma at baseline and (**B**) 3 weeks after four treatments with nonfractional picosecond laser; treatment parameter: 1064 nm, 450 ps, 0.91 to 1.18 J/cm^2, 3 Hz, 6 mm.

Postinflammatory hyperpigmentation

PIH is characterized by an acquired increase in pigmentation secondary to an inflammatory process and is a commonly observed response to cutaneous injury in melanin-rich Asian skin. The severity of PIH is related to the degree of inflammation and extent of disruption of the dermoepidermal junction. Such melanogenesis is increased the darker the skin type. Histologically, excess epidermal and dermal pigmentation can be seen.

Although a benign condition, PIH can cause significant anxiety and lowered self-esteem in patients. Its initial management involves early and effective treatment of the underlying skin condition, to minimize any inflammation that may cause further PIH. All potential irritants, such as fragrance or cosmeceuticals, should be stopped. Photoprotection is imperative. Treatment modalities to accelerate the normalization of skin color include topical agents, such as hydroquinone, retinoids, azelaic acid, kojic acid, glycolic and lactic acid, chemical peels, microdermabrasion, and laser treatment.

Different lasers have been used to improve PIH. Vascular lasers, such as the 595-nm LPDL, target mainly oxyhemoglobin, and can be used to treat the vascular component of the inflammatory process. When used with compression, it can also be effective for pigment removal. QS lasers, such as QS Nd:YAG and QS alexandrite, have long been successfully used to treat

cutaneous pigmentation. Depending on the wavelength used, epidermal and dermal pigmentation can be targeted accordingly. In recalcitrant PIH in which dermal pigment may be present, 1064-nm QS Nd:YAG has been successfully used in previous reports with minimal adverse effects. More recently, our group examined the management of acne PIH in Chinese patients and suggested the use of bleaching agents for the initial 3 months, followed by combination topical and laser therapy (LPDL and/or 1064-nm QS Nd:YAG) for recalcitrant PIH with vascular and dermal components (Fig. 10.11). Laser treatment in itself can of course be a cause of PIH in darker skin types, and strategies to reduce PIH risk include effective sun protection before and post procedure, the use of LP lasers, cooling, diascopy, and small spot sizes in this group.

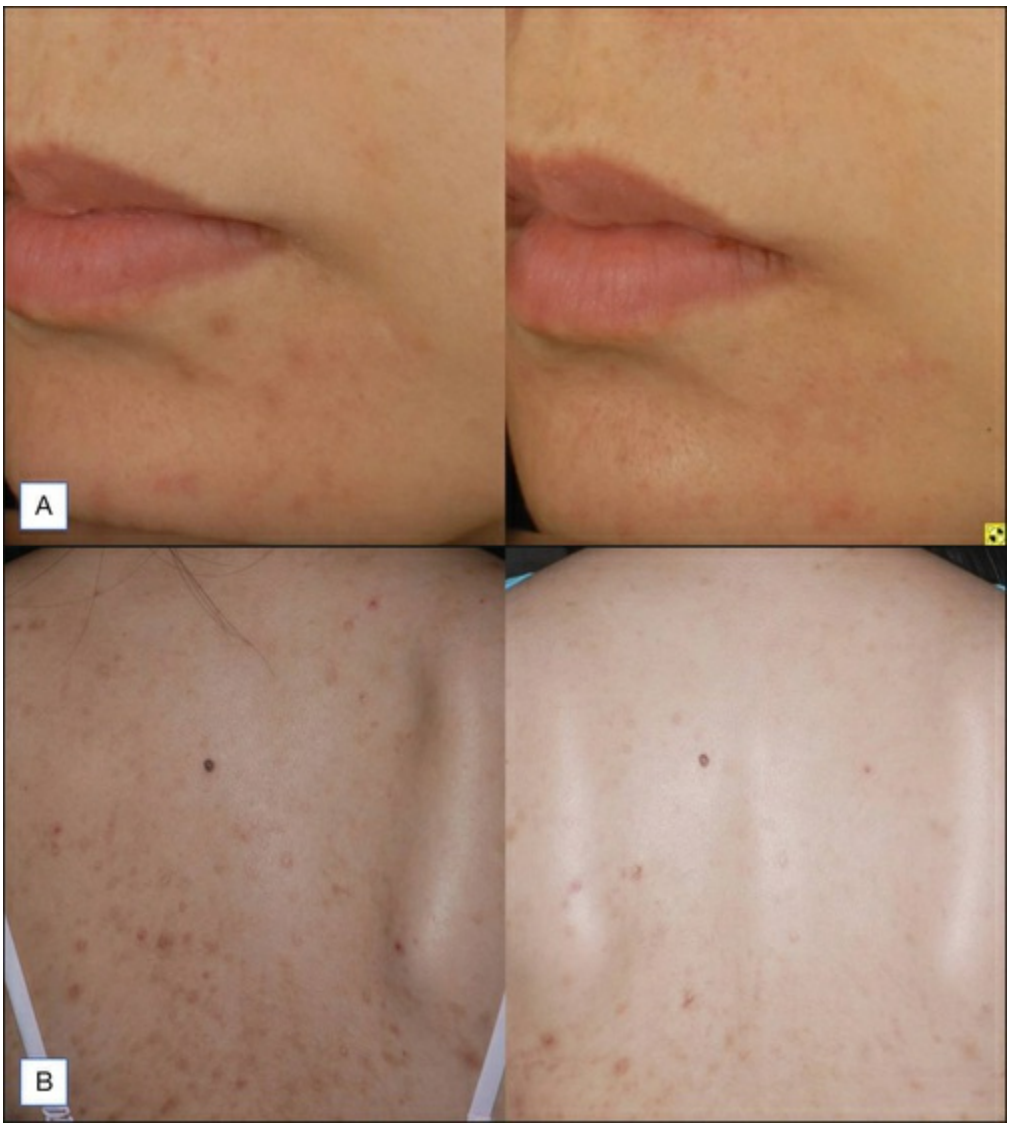


FIGURE 10.11 Management of acne PIH with different treatments: (**A**) 2 months after azelaic acid 20% + mometasone 0.1% cream + hydroquinone 4% cream. (**B**) After five treatments with QS 1064-nm Nd:YAG; treatment parameters: 3.1 J/cm^2, 8 mm, 10 Hz.

Picosecond lasers can also be used for the treatment of PIH with comparable results to nanosecond lasers (Fig. 10.12).

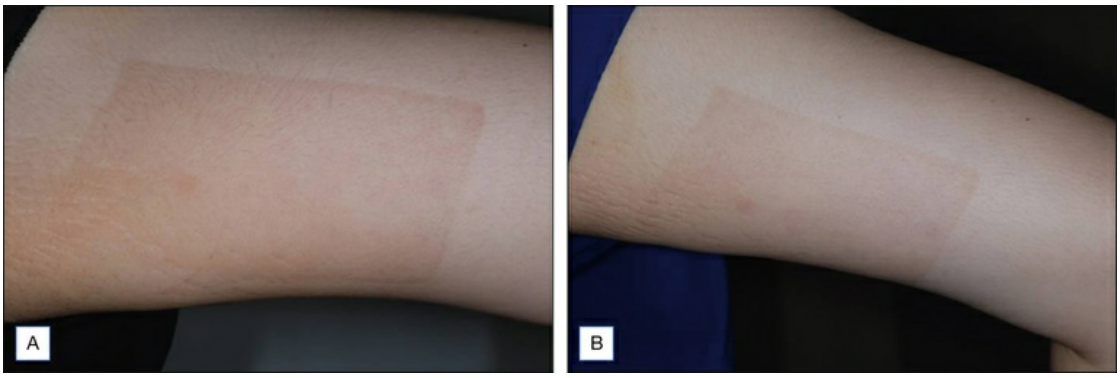


FIGURE 10.12 (**A**) PIH at baseline. (**B**) Improvement after a single picosecond laser; treatment parameters: 755 nm, 0.4 J/cm^2, 10 Hz, 8 mm.

Melanocytic nevi

Although the gold standard for the removal of melanocytic nevi is by excision followed by histologic examination, the resulting scar is often an undesired cosmetic outcome. Lasers have been used successfully to remove and lighten nevi with better cosmetic results. However the clinician needs to be aware of the potential risk of malignant transformation, and the patient's skin type, family history and location of lesion are important considerations. The incidence of melanoma has been reported to be between 0.2 and 2.2 per 100,000 in Asians, depending on skin type. Acral regions, such as the feet, appear to be more commonly affected. Laser treatment of melanocytic nevi may therefore be considered in darker-skinned individuals with no risk factors, and lesions in a nonacral location, after an explanation of the risks involved. The combination of CO_2 and QS alexandrite laser was reported to be successful in 11 patients with congenital nevi. Another study reported the successful use of QS ruby laser and normal-mode ruby laser for acquired melanocytic nevi. All flat lesions resolved, whereas compound lesions demonstrated only a partial response. The use of fractional resurfacing has now been incorporated into the treatment regimen. A typical treatment protocol is as follows: LP pigment laser (LP alexandrite 755 nm, 3 ms, 10-mm spot size, 15 to 25 J/cm^2 depending on the degree of pigmentation, with slight dark gray appearance being the end point), to be followed immediately by QS ruby laser (4-mm spot size, 3 to 4 J/cm^2, with immediate whitening as the end point). Four to 6 weeks later, the patient will be treated with NA FR using a combination of 1550- and 1927-nm wavelengths (1550 nm, four passes, 50 mJ, treatment level 10, to be followed by 1927 nm, four passes, 20 mJ, treatment level 10). Such alternate treatment at 4- to 6-weekly intervals is performed until the nevi completely lighten (Case Study 5).

Case Study 5

Melanocytic Nevi (Fig. 10.22)



FIGURE 10.22 Successful lightening of melanocytic nevi with LP alexandrite and QS ruby laser.

A 34-year-old Chinese male requested for two moles on his right cheek to be removed. He has no family history of any skin malignancies, and his moles have not changed for several years. Examination showed a dark brown junctional nevus and another brown compound nevus on his cheek. During the consultation, the need for multiple treatments and risk of PIH were discussed. It was also explained that there may not be complete clearance and recurrence may occur.

The patient underwent treatment with three sessions of LP alexandrite (20 J/cm^2, 3 × 10-mm spot size, 3 ms) followed by three sessions of QS ruby (3.2–3.4 J/cm^2, 4-mm spot size) at 4- to 6-weekly intervals until the nevi sufficiently lightened.

More recently, for very large congenital melanocytic nevi that cover a large area of the face, picosecond lasers to be followed immediately by nonablative (under 6 months of age) or AFR (over 6 months of age) have been used to reduce the risk of excessive epidermal injury associated with the aforementioned combination approach with LP and QS lasers. The idea is to remove the visible superficial pigment with the picosecond laser, and the AFR works in a fractional manner to nonspecifically reduce the bulk of the deeper dermal melanocytic mass (Fig. 10.13). In our experience, young children tolerate the procedure well and heal easily despite the more aggressive nature of the fractional ablative treatment.



FIGURE 10.13 (**A**) Congenital melanocytic nevi at baseline and (**B**) after 13 treatments with picosecond laser (treatment parameters: 755 nm, 0.87 to 4.07 J/cm^2, 10 Hz, 2.5 to 5.4 mm) and ablative fractional resurfacing (treatment parameters: 1550 nm, 60 mJ, 0.85 kJ, 56 MTZ cm^2).

Treatment of vascular lesions

Vascular specific lasers induce vessel injury and have been used to target vascular lesions, such as port-wine stains (PWSs), telangiectasia, and scars, as well as for nonablative skin rejuvenation. One of the principal absorption peaks of oxyhemoglobin is at 577 nm, with a smaller peak around 700 to 1100 nm; 585- and 595-nm pulsed dye laser (PDL), being close to the 577 nm peak, have shown excellent efficacy and safety in the treatment of PWSs in Asians, as well as hypertrophic scars, which are found more commonly in darker skin types.

Asahina et al. evaluated the use of 595-nm PDL (7-mm spot size, 10-ms pulse duration, 12 J/cm^2) in the treatment of PWSs in skin type IV patients and found 67% of patients achieving good or excellent results after four treatments at 8-week intervals. Hyperpigmentation and hypopigmentation were seen in up to 17% and 14%, respectively. Epidermal cooling and protection enhances efficacy by allowing a higher fluence to be used to achieve the desired endpoint of purpura with better tolerability and less side effects in darker skin types (585-nm PDL, 7-mm spot size, 1.5 ms, 7 to 13 J/cm^2, dynamic cooling device with 20-ms spray and 30-ms delay interval) (Fig. 10.14). However, complete blanching of PWSs is rarely seen. It has been postulated that regeneration and revascularization of photocoagulated blood vessels due to angiogenesis occurs as part of the skin's normal healing process. The heterogeneity of vessels characteristic of PWS requires the use of different spot sizes, fluences, pulse

widths, and dynamic cooling, depending on vessel size and anatomic location. Due to a greater risk of dyspigmentation when treating lip PWSs with PDL, a 1064-nm Nd:YAG is recommended. Combined 595- and 1064-nm laser irradiation has also been recommended for recalcitrant and hypertrophic PWSs.

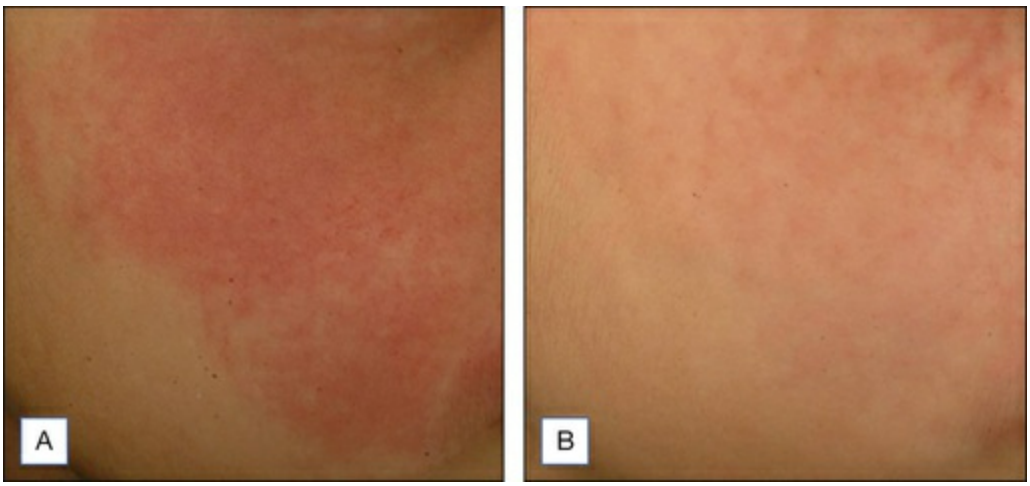


FIGURE 10.14 (**A**) PWS at baseline and (**B**) marked improvement of PWS after eight LPDL treatments.

LP millisecond 1064-nm Nd:YAG lasers target the lesser absorption peak of oxyhemoglobin in the infrared range and have been used in the treatment of large telangiectasia and reticular veins because they allow for deeper dermal penetration. The longer wavelength also results in minimal absorption by epidermal melanin, conferring a safe and effective treatment in patients with ethnic skin. LP 755-nm alexandrite laser has also been reported to improve vessels after a single treatment, but PIH is seen in 30% of patients, possibly due to hemosiderin deposition and/or excessive cooling.

Facial telangiectasia is a common dermatologic complaint and may be associated with rosacea, photodamage, prolonged topical corticosteroid use, liver disease, radiodermatitis, and connective tissue disease. PDL is presently regarded as the treatment of choice, due to its excellent efficacy and safety profile. However, purpura and/or PIH can occur at the treated site and is generally unacceptable to most patients, and hence studies comparing the efficacy of purpuric and subpurpuric PDL treatment for facial telangiectasia. In a split-face study, purpuric settings achieved a greater reduction in telangiectasia density in 82% of patients (7-mm spot size, 10-ms pulse duration, fluence 8.5 to 10 J/cm^2, dynamic cooling device [DCD] 30-ms spray, and 20-ms delay interval). Another study showed subpurpuric treatment with PDL (7-mm spot size, pulse duration 6 ms, fluence 7 to 9 J/cm^2) resulted in 75% of patients achieving greater than 25% improvement after a single treatment. This is generally preferred due to minimal downtime, although the lack of a visible end point may lead to subtherapeutic treatment and the need for more treatments to achieve the desired outcome. Further studies have suggested the use of dual-wavelength laser treatments with sequential subpurpuric delivery

of 595- and 1064-nm radiation demonstrating better results when compared with single-wavelength treatment after a single treatment session.

The use of PDL has additionally been demonstrated to be effective in the treatment of hypertrophic scars, which are more common in darker-skinned patients. Improvements in skin texture, bulk, and scar texture have been reported. In patients with highly melanized skin, lower fluences are used to minimize PIH. Relatively low energy (10-mm spot size, 0.45 to 1.5 ms, 4.5 to 5.0 J/cm^2) at 2-month intervals are used when using PDL to treat hypertrophic scars in ethnic skin, and in thin-skinned areas, such as the chest and neck. Epidermal skin cooling can also help to reduce the risk of dyspigmentation.

Ablative, nonablative, and fractional skin resurfacing

Ablative resurfacing with carbon dioxide (CO_2) and Er:YAG lasers have long been the gold standard. They target water as a chromophore, leading to epidermal and dermal vaporization and ablation of 100 to 200 μm in depth. Although clinically effective in improving rhytides, atrophic scarring and dyschromia, there is significant associated down time and potential side effects, including persistent erythema, hyperpigmentation and hypopigmentation, infection, and even scarring, especially in dark skin.

Patients with darker skin are seeking alternative skin resurfacing treatments with lower risk profiles. Nonablative lasers that deliver laser, light-based, or radiofrequency energy to the skin have been the focus of the shift in recent years, and these include PDL, IPL, Nd:YAG, diode, and Er:glass lasers. Modest improvement in skin texture, scars, and rhytides is typically produced after a series of monthly treatments using these devices. There is little downtime associated, and adverse effects, such as PIH and scarring, are much less when compared with ablative devices.

Radiofrequency has been used successfully for noninvasive skin rejuvenation. The radiofrequency device delivers an electric current that nonselectively generates heat by the tissue's natural resistance to the flow of ions. Epidermal cooling from the cooling tip protects against melanin disruption, and radiofrequency can be safely applied to any skin type. Such delivery of energy deep into 2 to 4 mm of the dermis induces subtle collagen damage and subsequent healing and remodeling, resulting in immediate skin tightening and further improvement after several months. Monopolar radiofrequency is a helpful tool for noninvasive skin tightening for patients with mild-to-moderate skin laxity; however, some discomfort during treatment is expected (Fig. 10.15). Patient feedback on heat sensation is thought to be a valid and preferred method for optimal energy selection. Multiple passes at moderate energy settings have yielded good and consistent results. Newer models have incorporated a vibrating handpiece, to reduce the sensation of pain, in accordance with the gate theory of pain.

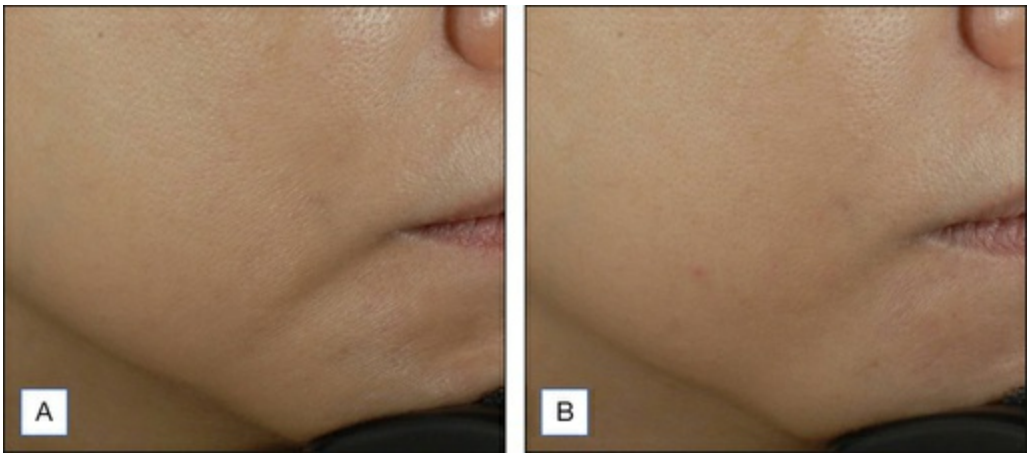


FIGURE 10.15 (**A**) Baseline and (**B**) 5 months after monopolar radiofrequency for skin tightening.

Focused ultrasound is another device that can be used to noninvasively tighten the skin. High-intensity focused ultrasound translates sound waves into thermal energy; in addition, it allows imaging of the tissue before application of the focused ultrasound directly to the target area. A study on 49 Chinese patients has shown early promising results with significant improvement to the lower face and a good safety profile with only transient bruising, erythema, edema, and PIH described (Fig. 10.16).

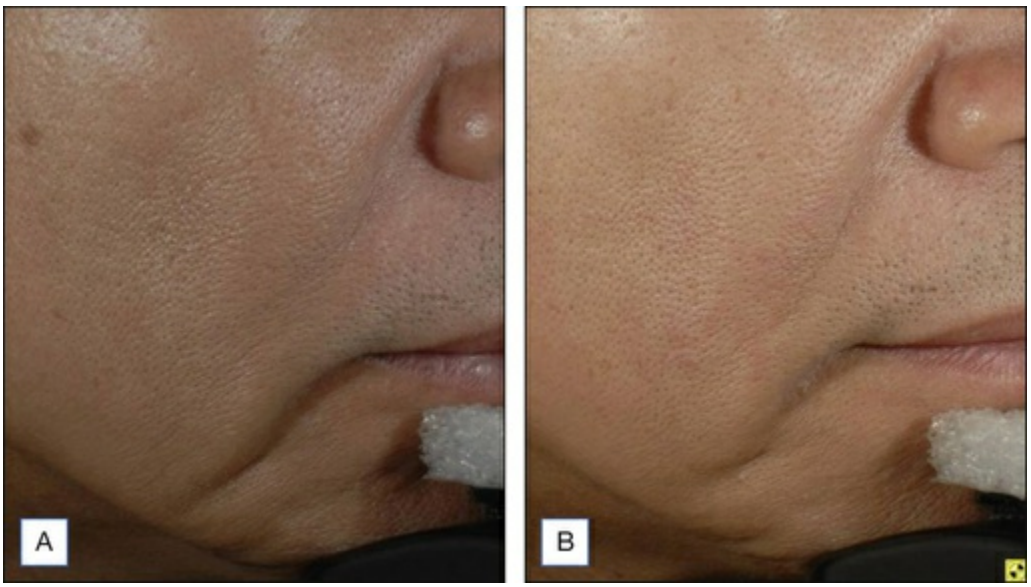


FIGURE 10.16 (**A**) Baseline and (**B**) 3 months after focused ultrasound treatment; treatment parameter: 1.2 J.

The development of fractional photothermolysis has revolutionized skin rejuvenation and resurfacing, attempting to achieve comparable clinical results to ablative lasers, but with a safety profile more similar to nonablative technologies. The 1550-nm erbium-doped fiber nonablative laser is the first fractional laser approved for clinical use. By creating an array of microscopic

treatment zones (MTZs) with controlled width, depth, and density, a fixed percentage of the skin is thermally coagulated in each treatment session, leaving an intact stratum corneum. Healthy tissue surrounding these MTZs allows for rapid healing and reepithelialization within 1 day. This technology has proven to be effective in improving photoaging, dyschromia, rhytides, atrophic scarring, and poikiloderma. NA FR used for acne scarring in Asian skin carries a high risk of PIH. Studies have indicated that treatment density, rather than energy, is a stronger determining factor in the development of PIH. Further studies have confirmed that by reducing the number of passes and the total treatment density (four passes rather than eight passes), but increasing the treatment sessions from three to six to compensate for the reduced passes, clinical efficacy remains statistically improved while reducing the PIH risk in Asians from 18.2% to 6% (Fig. 10.17).

Pearl 7

In nonablative fractional resurfacing, reducing the treatment density and increasing the number of treatment sessions can reduce the PIH risk in ethnic skin.

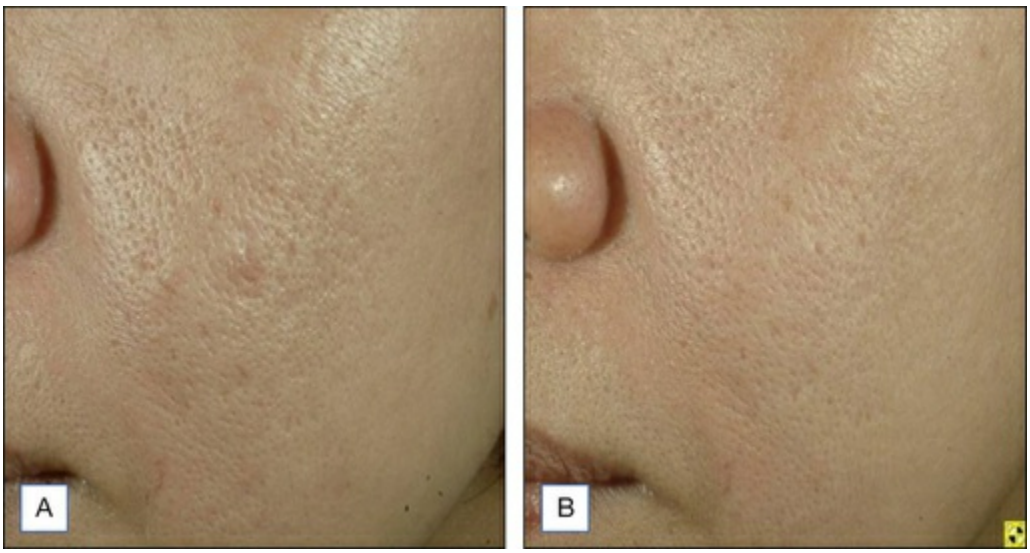


FIGURE 10.17 (**A**) Acne scarring at baseline and (**B**) 1 month after eight treatments of 1550-nm NA FR with four passes during each treatment; treatment parameters: pulse energy 60 mJ, total energy 3.05 kJ, total density 125 MTZ/cm^2.

Low-energy, low-density NA FR using 1440-nm diode laser or 192-nm thulium laser can be particularly applicable to skin of color, given the lesser degree of wrinkling but more pigmentary issues in this population. A study indicated that low-energy and low-density 1440-nm diode laser can be effective for the treatment of pigmentation and skin texture, especially among younger Chinese with limited adverse effects and downtime.

More recently, AFR has been investigated for photorejuvenation and acne

scarring in Asian skin. Studies using a fractional CO_2 ablative device on nine Chinese patients found improvement in skin texture, skin laxity, wrinkles, enlarged pores, and acne scars, with 55.5% and 11.1% PIH risk at 1 and 6 months, respectively.

Other methods to reduce the risk of PIH in patients with skin of color after AFR include a reduction of treatment density of each ablative fractional session which subsequently increases the number of treatment sessions required for the desired clinical outcome. The use of topical and oral steroids has also been advocated, but risk of infection has to be taken into consideration.[2-4] Other fractional ablative devices, such as fractional Er:YAG or radiofrequency, have been studied, and data indicate a slightly lower risk of PIH.

Fractionated picosecond lasers have also been used to treat acne scars.[5] In our experience, picosecond lasers are associated with a lower risk of adverse effects, as compared with NA FR for the treatment of acne scars. However, to date, we have yet to achieve the same clinical results with picosecond lasers as compared with those seen after NA FR laser treatments for acne scars.

Conclusion

With the rapid evolution of demographics globally, increasing numbers of patients with ethnic skin will present to dermatologists seeking laser treatment for cosmetic enhancement. Understanding and establishing treatment protocols with appropriate parameters for all skin types is essential in the running of a successful practice.

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11

Complications and legal considerations of laser and light treatments

David J. Goldberg

Summary and Key Features

- Complications
- Lasers
- Light sources
- Scars
- Pigmentary changes
- Negligence
- Standard of care
- Duty
- Breach of duty
- Causation
- Damages
- Medical malpractice
- Expert witness

Introduction

Laser and light therapy is a constantly evolving and improving area within the medical field. Although lasers were initially developed with medical purposes in mind, the gradual shift has been towards cosmetics. The variety of lasers and light treatments available can treat such things as wrinkles, scars, vascular lesions, unwanted hair, pigmentary disturbances, tattoos, and medical conditions, such as psoriasis, vitiligo, and acne. Lasers and light sources are currently included under a broad category that falls under the category of energy-based devices (EBDs). EBDs include not only lasers and light sources, but also radiofrequency, ultrasound, and microwave devices. There are a few general points in terms of EBD that will be discussed, after which more specific points will be made.

Complications are adverse events or responses to a therapy or procedure. Many complications that can arise are not laser specific; however, there are some complications that are more likely to arise with certain laser and light procedures and yet may be very uncommon with other EBD. A more general discussion leading to a more focused discussion on complications within certain subsets of lasers will follow.

Pearl 1

Complications are adverse events or responses to a therapy or procedure.

General considerations

It is beyond the scope of this chapter to discuss the specifics in setting up a laser unit. However, there are a number of medical-legal issues that can arise if laser treatments are done in unaccredited facilities, by untrained staff, or without the proper safety equipment.

Accreditation is a voluntary process by which a facility is able to measure itself against nationally recognized standards. There are several organizations through which a facility can accredit itself. The American Osteopathic Association (AOA), the Joint Commission on Accreditation of Health Care Organizations (JCAHO), and the Accreditation Association for Ambulatory Health Care (AAAHC) all accredit organizations and facilities.

Displaying certificates of accreditation serves as a reassurance to patients, the public, and to other health care professionals that a facility has met an independent standard of quality.

The geographic location of where treatments are done will determine the regulations of who can use a laser or light device. Each regulatory board has different rules. In some jurisdictions, only a physician may legally operate a laser or light device. Other jurisdictions require a certain amount of training and certification. Some require that a physician has evaluated the patient before the procedure is performed. It is up to the individuals involved to find out the established rules of their jurisdiction.

Eye protection within the workplace is mandated depending on location. In the United States, guidance for protective eyewear is outlined by the American National Standards Institute (ANSI) Z136 series. This is published and constructed by the Laser Institute of America (LIA). In Europe, eye protection guidelines are outlined in the EN 207. Further suggestions include warning signs on the door to warn anyone entering the operating room.

Complications

The many mechanisms of action of various EBDs lead to the potential for many different complications. Some lead to more frequent and/or more serious complications. However, most laser and light devices work by the principles of selective photothermolysis, and thus these complications can be discussed together.

Pearl 2

Laser and light source complications are rare but do occur.

General complications

The most common complications of laser treatment are: burning, prolonged erythema, hypopigmentation or hyperpigmentation, reactivation of herpes simplex virus (HSV), and acneiform eruption. These complications can occur from lasers, light sources, radiofrequency, ultrasound, and microwave-generated technologies.

Burning can be a common complication of a variety of lasers. Burning can occur with any EBD. When a burn occurs, it is usually due to one of three possible causes: too high a fluence, too short a pulse duration, or insufficient epidermal cooling. Most lasers have initial recommended settings, which are fairly safe parameters with appropriate technique and adequate epidermal cooling. Depending on the severity of the burn, there is usually little that is required in terms of treatment. With only a slight burn, there may be prolonged erythema. However, with a more severe burn, blistering and scarring may develop. Occurrences of more severe hypertrophic scarring have been minimized with the advent of newer technology and the disuse of more scar-prone lasers, such as the continuous wave argon laser.

Prolonged erythema can be defined in a number of ways. Erythema is an expected result with the use of most EBDs. The duration of erythema is often only 24 to 72 hours. Prolonged erythema has been reported with all laser and light devices. In general, no treatment is required except reassurance. Nonablative lasers generally have a shorter duration of erythema, whereas ablative resurfacing lasers have a higher rate of persistent erythema, which can last from weeks to several months.

Hyperpigmentation (Fig. 11.1) is a very common complication and possibly

the most common in darker skin types (see the study by Sriprachya-anunt et al.). It has been described with the use of almost every laser and light device in darker skin types. It is much less common in other EBD that are not well absorbed by melanin. In one study by Moreno-Arias et al., it was observed in 16% of patients undergoing intense pulsed-light (IPL) treatment. Goh reported that it can be as high as 45% in patients with skin types IV to VI. Wareham et al. reported that the pulse dye laser can cause hyperpigmentation, especially on the lower legs and where there is inadequate posttreatment sun protection and sun avoidance. Hyperpigmentation was also seen by Chowdhury et al. with the potassium titanyl phosphate (KTP) laser. With the ablative CO_2 laser, postinflammatory hyperpigmentation (PIH) is common and was reported by Badawi et al. to occur in 20% to 30% of Fitzpatrick III and 100% of Fitzpatrick IV patients. Mahmoud et al. found the erbium-doped yttrium-aluminum-garnet (Er:YAG) laser to have a PIH rate of 50% in patients with skin types IV to V (Fig. 11.2). Even nonablative fractional lasers can cause problems with PIH; in a 2010 study by Chan et al. there was an 18.2% rate in 47 patients treated. Although rarer, PIH has also been reported (e.g., by Choudhary et al. and Kuperman-Beade et al.) to occur with the use of Q-switched lasers. In darker skin types it can be fairly common; it was reported by Lapidoth and Aharonowitz to occur in up to 44% of darker-skinned patients. As noted above, vascular lasers were also found by Clark et al. to result in PIH, albeit more rarely.



FIGURE 11.1 Postinflammatory hyperpigmentation following treatment with the Q-switched Nd:YAG laser.



FIGURE 11.2 Postinflammatory hyperpigmentation following treatment with the erbium:YAG laser.

Hypopigmentation is a less common complication and is most commonly seen with the use of Q-switched lasers for tattoo removal, as well as vascular lasers for port-wine stains. Hypopigmentation from Q-switched lasers may be transient, but it can also be permanent. Depigmentation was also reported (by Fitzpatrick and Goldman) to occur with Q-switched lasers. In the treatment of port-wine stains the pulse dye laser has incidence rates of 2% to 31% of hypopigmentation. Longer pulse durations with the pulse dye laser seem to lessen the possibility of this complication. The ablative lasers have all been found to cause hypopigmentation (e.g., studies by Trelles and by Ward and Baker). Permanent hypopigmentation has also been described with the use of the CO_2 laser and, in a 10-year follow-up study by Prado et al., 8.7% of patients had problems with permanent hypopigmentation.

Reactivation of HSV is a possible complication for which prophylactic antivirals are often given, especially with resurfacing lasers. However, in a retrospective study by Trelles of patients not given antiviral prophylaxis, less than 1% of 600 patients developed reactivation of HSV with the use of a resurfacing laser. In another retrospective study by Campbell and Goldman, only 1.1% of 373 patients developed herpes reactivation with fractionated CO_2 laser resurfacing. Despite a low incidence rate, the potential for scarring with disseminated HSV infection can make this a serious complication.

Acneiform eruptions can occur with any laser and light device and may be due to either procedure or aftercare. Reported rates depend on the treatment, but in the three studies by Campbell and Goldman, Nanni and Alster, and Neaman et al. they ranged from 3% to 15% of patients with resurfacing lasers. This is a relatively benign complication with self-resolution expected.

Scarring has been reported with almost every cutaneous laser and light source (Figs. 11.3 to 11.6). The actual incidence is fairly small, yet overaggressive treatment with any laser or light device can cause it. Hypertrophic scarring is most common with the older continuous wave lasers, most of which are no longer commonly used in office practice.



FIGURE 11.3 Hypopigmentation and scarring following treatment with the pulsed dye laser.



FIGURE 11.4 Scarring following treatment with the carbon dioxide laser.



FIGURE 11.5 Scarring following laser hair removal.



FIGURE 11.6 Scarring following treatment with an intense pulsed light.

Specific laser complications

The complications covered above are common to almost all laser and light devices. However, there are some specific complications or considerations of various subsets of lasers.

Q-switched lasers

In the study by Kuperman-Beade et al., the most common adverse effects of the Q-switched lasers included hypopigmentation and hyperpigmentation, textural

change, and scarring after treatment (see Fig. 11.1). Melanin is the main competing chromophore and transient hypopigmentation, as well as permanent depigmentation with the Q-switched ruby laser can be seen (see the study above and those by Bernstein and Choudhary et al.). Grevelink et al. found that the Q-switched neodymium:yttrium-aluminum-garnet (Nd:YAG) laser with its longer wavelength has less chance of hypopigmentation than the Q-switched ruby laser. In darker-skinned individuals, if a Q-switched laser other than the Nd:YAG laser is used then decreasing the fluence may help to prevent hypopigmentation, according to Kuperman-Beade et al.

Hyperpigmentation is less common with the Q-switched lasers than hypopigmentation; however, Choudhary et al. found that bleaching agents may help to prevent this in the treatment of darker-skinned individuals and that the use of longer wavelength lasers may also minimize hyperpigmentation. Textural change is rarer and can be seen with an incidence of up to 12% with the alexandrite laser, as reported in the study by Fitzpatrick and Goldman.

A rarer but reported side effect is an allergic reaction post treatment. In studies by Kuperman-Beade et al., England et al., and Ashinoff et al., this was mostly seen with red cinnabar pigment and can present as a nodular scaly pruritic eruption or as an immediate urticarial eruption. Ashinoff et al. reported that this may be secondary to extracellular dispersal of tattoo pigment.

Paradoxical tattoo pigment darkening is a well-recognized possible complication when treating red, pink, skin tone, and white dyes. Kuperman-Beade et al. found that it can rarely also happen with blue, green, and yellow dyes. The reductions of ferric and titanium dioxide are thought to be the causative factor in this darkening. This darkening is often resistant to further treatment by Q-switched lasers. Furthermore, Arndt et al. found that Q-switched laser treatment in a patient with any history of gold salt ingestion will produce a permanent dark blue dyspigmentation know as chrysiasis. Chrysiasis can be challenging to treat, however, long pulsed lasers including the ruby and alexandrite have been used.

A rare but very serious complication is compartment syndrome. This was reported by Kuperman-Beade et al. and by Rheingold et al. in the circumferential treatment of the forearm with a Q-switched Nd:YAG laser.

Fractionated nonablative lasers

The fractionated nonablative lasers are well tolerated in most patients and have few complications. Hardaway et al. found that usually only mild, transient pain, erythema, and edema are seen. Studies by Chan et al., Laubach et al., and Tanzi et al. concluded that dyschromia is fairly uncommon compared with standard ablative lasers. To halve the risk of PIH, Chan et al. recommended that the microthermal zone (MTZ) density be decreased by half and more treatments are given. Blistering, acneiform eruptions, milia, reactivation of HSV infections, and scarring are rare complications.

Ablative lasers

The ablative lasers have come a long way in terms of safety. From continuous wave to pattern scanner to fractionated technology, technology has continuously been updated to improve safety while retaining efficacy. Continuous wave CO_2 lasers had a high incidence of scarring and hypertrophic scarring, along with pigmentary disturbances.

For the most part, fractionated technology is being used in combination with ablative lasers to improve safety. However, even with fractionation, hypertrophic scarring of the neck has been reported (e.g., by Avram et al. with fractionated CO_2 laser resurfacing). The incidence of pigmentation issues may be less with fractionated radiofrequency devices. In a study undertaken by Goldberg et al., fractionated radiofrequency treatments were undertaken in Fitzpatrick VI individuals without pigmentation problems.

Long-term hypopigmentation in the use of CO_2 laser resurfacing was reported by Ward and Baker. It seems to be more common in fair-skinned individuals. There is some evidence (by Grimes et al.) that hypopigmentation is a result of suppressed melanogenesis rather than true destruction of melanocytes, and treatment with the excimer laser was shown by Raulin to repigment hypopigmented areas. Transient ectropion has additionally been reported by Neaman et al. to occur very rarely as a potential complication. Milia also occurred in Nanni and Alster's study in up to 10% of patients after resurfacing; this can easily be treated with standard extraction.

Infections are fairly uncommon but can be bacterial, viral, and/or fungal, as found in the study by Alam et al. Dissemination of the wart virus with transient eruption and subsequent self-resolution has been described by Torezan et al. Abscess formation with *Mycobacterium fortuitum* 1 month after CO_2 laser resurfacing was also reported by Rao et al.

Vascular lasers

The vascular lasers have become safer over time. The advent of pulsed rather than continuous lasers, better cooling technology, and the understanding of selective photothermolysis have advanced the safety profile tremendously. However, there are still a few complications commonly seen. Purpura is expected with the use of the pulse dye laser with short pulse durations and high fluences. Iyer and Fitzpatrick reported that lower fluences with multiple passes or cautious pulse stacking can be performed to achieve similar results without purpura. Long pulse durations can also eliminate posttreatment purpura. Rarely, there can be textural change, with an incidence of less than 1% in the treatment of port-wine stains in the studies by Kono et al. and Levine and Geronemus (see Fig. 11.3). The latter also found that PIH can be common if there is sunlight exposure post treatment, so sun avoidance or protection needs to be used. Older vascular lasers had a much higher incidence of complications, with the argon laser notorious for causing atrophic hypopigmented scars. Olbricht et al. found that another notable complication with the argon laser was hypertrophic scarring and prolonged wound healing.

Intense pulsed-light-specific complications

IPL treatment is very well tolerated in general, but it has a higher learning curve with an increased number of variables. These variables include filters, pulse duration, fluence, the ability to double or triple pulse, and a variety of indications. Crusting and blistering occur in approximately 2% to 16% of patients; furthermore, persistent local heat sensation lasting longer than 24 hours occurs in 2% of patients. A rare complication of IPL treatment seen by Vlachos and Kontoes was the development of terminal hairs within a treated port-wine stain. Scarring has been only rarely reported (see the studies by Ho et al. and Raulin et al. and Fig. 11.6). Treatment of tanned patients can produce obvious hypopigmentation. Paradoxical hair growth was first reported with IPL treatment, but can also occur after laser hair removal treatment. Transient hypopigmentation and PIH, especially in patients with darker skin and Mediterranean or middle-eastern background can occur with IPL. Leukotrichia was also found to develop, along with temporary color change from black to yellow color, in studies by Radmanesh et al.

Legal aspects

Regardless of training, quality of equipment, and rigidity in patient selection, it is almost inevitable that, over a lifetime, certain complications will occur in the hands of any health care practitioner. In most cases these will not result in legal action. However, if legal action is taken, then the most common interaction between a health care operator and health care law is in the realm of negligence.

Four elements must be present for there to be cause of action in negligence: duty, breach of duty, causation, and damages. A suing plaintiff must show the presence of all four elements to be successful in his or her claim.

Pearl 3

Negligence requires proof of duty, breach of duty, causation, and damages.

The duty of a physician performing energy-based laser or light treatments is to perform that procedure in accordance with the "standard of care." Although the elements of a cause of action in negligence are derived from formal legal textbooks, the standard of care is not necessarily derived from a textbook. It is also not articulated by any judge. The standard of care is defined by some as whatever an expert witness says it is and what a jury will believe. In a case against a physician performing EBD treatments, the specialist must have the knowledge and skill ordinarily possessed by a specialist in that field and have used the care and skill ordinarily possessed by a specialist in that field in the same or similar locality under similar circumstances. A dermatologist, physician extender, or for that matter an internist performing these procedures will all be held to an equal standard. A failure to fulfill such a duty may lead to loss of a lawsuit by that individual. If the jury accepts the suggestion that the

provider mismanaged the case and that the negligence led to damage of the patient, then liability will ensue. Conversely, if the jury believes an expert who testifies for a defendant doctor, then the standard of care in that particular case has been met. In this view the standard of care is a pragmatic concept, decided case by case and based on the testimony of an expert physician. The sued physician is expected to perform the procedure in a manner of a reasonable physician. He or she need not be the best in his/her field but need only perform the procedure in a manner that is considered by an objective standard as reasonable.

It is important to note that where there are two or more recognized laser methods of treating the same condition, a physician does not fall below the standard of care by using any of the acceptable methods, even if one method turns out to be less effective than another method. Finally, in many jurisdictions, an unfavorable result due to an "error in judgment" by a physician is not in and of itself a violation of the standard of care if the physician acted appropriately prior to exercising his/her professional judgment.

Pearl 4

There may be more than one accepted laser approach. Choosing one, and not the other, is not a breach of duty.

Evidence of the standard of care in a specific malpractice case includes laws, regulations, and guidelines for practice, which represent a consensus among professionals on a topic involving diagnosis or treatment, and the medical literature including peer-reviewed articles and authoritative texts. In addition, the view of an expert is crucial. Although the standard of care may vary from state to state, it is typically defined as a national standard by the profession at large.

Most commonly, for litigation purposes, expert witnesses articulate the standard of care. The basis of the expert witness and the origin of the standard of care is grounded in the following:

1. The witness' personal practice and/or

2. The practice of others that he has observed in his experience; and/or

3. Medical literature in recognized publications; and/or

4. Statutes and/or legislative rules; and/or

5. Courses where the subject is discussed and taught in a well-defined manner.

Pearl 5

Expert witnesses articulate the standard of care.

The standard of care is the way in which the majority of the physicians in a similar medical community would practice. It is the method by which other laser physicians deal with their daily performance of cosmetic dermatology. If indeed the expert does not practice like the majority of other physicians, then the expert will have a difficult time explaining why the majority of the medical community does not practice according to his/her ways.

Pearl 6

A complication is not proof of negligence.

Complications following laser- and light-based treatments can occur. They are not necessarily acts of negligence. If the treating provider acts in accordance with the standard of care, it is unlikely that the physician will lose a lawsuit based on negligence.

Further reading

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